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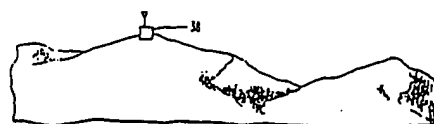
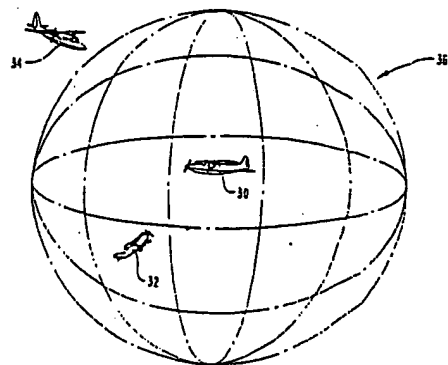
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(54) Title: A UNIVERSAL DYNAMIC NAVIGATION, SURVEILLANCE, EMERGENCY LOCATION, AND COLLISION AVOIDANCE SYSTEM AND METHOD

(57) Abstract

A craft tracking and collision avoidance system is disclosed. The system allows the positions of a plurality of craft (30, 32) either on land, sea, air or space, to be monitored. Each craft (30, 32) determines its own position using an existing position determining system (100) such as LORAN or GPS. Each craft (30, 32) then transmits a radio frequency signal in to which position information, preferably identifying information and other messages, have been encoded. Each craft (30, 32) broadcasts its position, identifying information and other messages on a regular basis without the need for any interrogation signal. The broadcast position and identification information can be received by other craft and, since each craft (30, 32) has determined its own position, can be used to determine the proximity and identity of other craft, and if the craft are on a collision course. Preferably, the position of all the craft (30, 32) within a predetermined range (36) of a craft (30) is represented on a display in order to give the craft operator a visual indication of traffic surrounding his craft (30).



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A UNIVERSAL DYNAMIC NAVIGATION,
SURVEILLANCE, EMERGENCY LOCATION, AND
COLLISION AVOIDANCE SYSTEM AND METHOD

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BACKGROUND

1. The Field of the Invention.

This invention relates to systems and methods for automatically announcing the position of one or more mobile craft to a receiver positioned at a remote location. More particularly, the present invention relates to systems and methods for tracking the positions of a plurality of mobile craft so as to provide assistance in navigation, surveillance, emergency location and collision avoidance.

2. The Prior Art.

Throughout recorded history there has been an ever increasing need for more precise navigational aids. Through the years, the time keeping and position determining devices used for navigation have evolved from sun dials and sextants to sophisticated digital electronic systems capable of providing nearly pinpoint positioning accuracy almost anywhere in the world.

In today's transportation and communications environment, many devices exist that provide specific navigational aid to the operators of air, sea, and land craft. Navigational aids such as the Global Positioning Satellite system (GPS), the Long Range Navigation system (LORAN), and other navigational aids commonly referred to by such various acronyms as: VOR-DME, VOR-TACAN, DECCA, OMEGA, NDB, ILS, MLS, and ADF, are used by craft operators, particularly aircraft pilots, to determine the position of their craft in one, two, or three planes in space. For example, an operator of an aircraft may only desire to know the position of the craft above or below the surface of the earth (altitude or depth) or may desire to know only the

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position of the craft relative to a fixed terrestrial reference system (latitude and longitude) or the operator may desire to know the craft's position in all three planes in space.

One of the purposes of the various available navigational aids is to allow operators of craft, in particular air and water craft, to avoid collisions between their craft. As is well known, mid-air collisions of aircraft almost always result in disastrous loss of life and property. In an effort to avoid collisions between craft, various systems have been implemented in the air and marine transportation industries.

In the United States, government agencies dealing with the air transportation industry have recognized a need to prevent mid-air collisions. In an effort to reduce the occurrence of mid-air collisions, U.S. government agencies have mandated that by the end of 1991 all commercial aircraft with thirty or more seats be equipped with collision avoidance equipment. Several types of collision avoidance equipment have been devised and are classified as either "active" or "passive" systems. These systems are commonly designated as Traffic Alert and Collision Avoidance Systems, also referred to as TCAS.

TCAS has been designed as a primary collision avoidance system for commercial aircraft and has received the United States Federal Aviation Administration's approval. An "active" TCAS system (TCAS II or III) provides the capability to interrogate other nearby transponder-equipped aircraft to elicit a responsive reply, while "passive" TCAS systems (TCAS I) simply eavesdrop on nearby interrogation replies from other transponders. In order to detect a "bearing," a TCAS system requires an expensive directional antenna.

The TCAS method is dependant upon either a secondary or beacon surveillance radar system, or other transponder (S) type interrogations in order to elicit a responsive reply. It is also transponder dependant, meaning that any aircraft not equipped with a transponder will not be detected, and any transponder not coupled to an altitude encoder will not deliver altitude information.

Recently, serious questions have been raised about how "safe" TCAS is in practice. TCAS operates in a narrow band of Air Traffic Control (ATC) radio frequencies in the microwave region of the spectrum. Thus, because of the number of interrogation requests and replies elicited, and the amount of information needed to be processed both TCAS and the ATC system may be "overwhelmed," and their operation sufficiently degraded to the point of "saturation," where the number of aircraft under the control of ATC exceeds the capacity of the system. Already, computer overloads and radar shutdowns have occurred at some busy locations. There is also the danger of a malfunction occurring, such as an item of interrogation equipment becoming stuck in the transmit mode, thereby "locking up" the entire system.

The high cost of the on board TCAS equipment makes its installation prohibitively expensive to most aircraft other than commercial aircraft. Moreover, TCAS III has not yet been fully developed. Even further, TCAS II and III are designed with the commercial aviation market in mind, but of the 215,926 active aircraft registered in the United States in 1988, the commercial aviation fleet only amounted to about three percent (3%) of the total. Thus, it is apparent that improved collision avoidance systems need to become more accessible to a much larger portion of the aviation industry, as well as to land and sea-based craft.

In view of these drawbacks and difficulties it would be an advance in the art to provide a complete traffic control system not requiring radar, and which provides a system and method for announcing the position of a craft to a remote receiver such that the position of the craft can be continuously monitored and collisions with other craft avoided. It would also be an advance in the art to provide a system and method for collision avoidance which may be used in addition to, and without interference with, preexisting collision avoidance systems and which can be economically implemented in the general aviation and marine industries so that, for example, with a single frequency select switch sea-going vessels could monitor air or land-based traffic and vice versa.

It would be a further advance in the art to provide a system and method which allows the operator of a first craft to monitor the position of a plurality of other craft within a predetermined range of the first craft and to alert the operator of a craft of a potential collision between craft as early as possible. It would be yet another advance in the art to provide a system and method for announcing the position of craft to other craft which are within a predetermined range which is reliable, does not distract an operator of a craft from other duties, and provides short and long range navigational assistance to the operator of a craft.

It would be a still further advance in the art to provide a system and method of tracking the position of one or more craft within a predetermined range of a location anywhere on the earth such as at a remote airstrip, or beneath the surface of the ocean, or in space. It would be an even further advance in the art to provide a collision avoidance system which does not become saturated in areas of heavy traffic and which is capable of assisting with the

1 landing or mooring of craft operating under poor visibility
conditions. Still further, it would be an advance in the
art to provide a system and method for tracking the
5 position of a number of craft, for example a fleet of land
craft which are carrying out tasks such as delivery of
goods or people or other tasks.

BRIEF SUMMARY OF THE INVENTION

10 The present invention allows the position of a first
craft to be monitored at a location remote from the craft.
The position of the craft can be monitored at a stationary
receiver or from on board another craft. Since a craft
equipped with the present invention can monitor the
15 position of other properly equipped craft, collisions
therebetween can be avoided.

In the case where the present invention is fully
implemented, i.e., all the craft in a fleet are equipped
with embodiments of the present invention, all the craft
are able to monitor the position of all other craft within
20 a predetermined range. Moreover, each craft is able to
accurately transmit its own position so the present
invention is a great aid to navigation.

The present invention includes means, on board a first
craft, for receiving or determining the position fix of the
25 first craft. Any number of position-determining devices
may be used. For example, the position of the first craft
may be obtained by using an altimeter or depth finder, the
widely accepted LORAN navigation system, or GPS position
determining techniques.

30 The position of the first craft is encoded, preferably
as a digital signal, so that the position information of
the first craft can be carried by a radio frequency signal.
Preferably, both the craft position fix, craft identif-
ication code, and other relevant information such as radio
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frequency number, directory advisories, and equipment error flags are encoded so they can be carried by the radio frequency signal.

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A large number of craft often operate within a limited range and may all transmit position information on the same radio frequency. In order to avoid interference with conflicting radio frequency signals, it is preferred that conflicting signals are listened for prior to transmitting the radio frequency signal.

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Importantly, the present invention does not require interrogation by a land-based, or other transmitter before position information will be transmitted by a craft. The radio frequency signal carrying the position information, and preferably other messages and identification information, is regularly transmitted on a continuous basis.

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The radio frequency signal which is transmitted (carrying at least the position information for the craft) is received by another craft or a stationary monitoring receiver at a remote location. The received radio frequency signal is decoded to extract the craft position, identification and other information therefrom. Using the position information, the position of the other craft is displayed.

20

If the radio frequency signal is received on board another craft, the position of the first craft is of great help to the operators of that craft to navigate, communicate and especially to avoid possible collisions. In order to aid the operators of that craft, the relative positions of each craft are also determined and preferably displayed.

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By displaying the positions of the two craft as the craft move, a heading for each of the craft can be derived and displayed and the possibility of a collision assessed.

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In accordance with the present invention, if a collision is

1 possible between two craft on their present headings the
operators of each craft are alerted so appropriate action
can be taken. It will be appreciated that the greatest
5 benefit from the present invention accrues when all craft
have an embodiment of the present invention on board. When
all the craft are so equipped, all of the craft can monitor
the position of all other craft which are within a
predetermined range.

10 Importantly, the present invention has applications
other than providing collision avoidance advice. The
present invention may be used as a navigational aid, for
example, by automatically displaying the craft's position
on a terrain map or graphically showing a landing approach.
15 Moreover, with appropriate navigation information, the
present invention may be implemented economically and some
embodiments of the invention may be used anywhere in the
world. Also, the embodiments of the present invention can
be used to locate and direct precision emergency location
and rescue efforts in the case of disabled craft.

20 Significantly, the present invention does not rely on
interrogation by other craft to transmit its position fix.
Rather, the radio frequency signal carrying the position
information is transmitted regardless of the presence of
any other craft or monitoring receiver. The strength of
25 the radio frequency signal is limited so that it is
received only within a predetermined range which is of
interest. For example, the predetermined range of the
radio frequency signal may be five, ten, thirty, or more
miles. Moreover, rather than requiring a sophisticated
30 radio direction finding antenna, the radio frequency signal
of the present invention is preferably transmitted
omnidirectionally so that all craft within the
predetermined range will be able to extract the position
information therefrom.

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BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the herein-recited
5 and other advantages and objects of the invention are
obtained can be appreciated, a more particular description
of the invention briefly described above will be rendered
by reference to a specific embodiment thereof which is
illustrated in the appended drawings. Understanding that
10 these drawings depict only a typical embodiment of the
invention and are not therefore to be considered limiting
of its scope, the invention will be described and explained
with additional specificity and detail through the use of
the accompanying drawings in which:

15 Figures 1A-1B are high level flow charts describing
the presently preferred steps carried out by the system
described herein.

Figure 2 depicts three aircraft as an example of the
operating environment of the described embodiment of the
20 present invention.

Figure 3 is a block diagram showing the major
functional components of the described embodiment.

Figures 4-1 through 4-11 provide a flow chart
describing the steps carried out by the preferred
25 embodiment of the apparatus of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made to the drawings wherein
like structures will be provided with like reference
30 designations.

1. General Discussion.

As discussed above, the widely promoted and available
collision avoidance systems, particularly those available
to the aviation industry, inherently have several
drawbacks. A major drawback is the fact that the cost of
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1 installing the necessary on board equipment may exceed the
cost of an entire small aircraft. Thus, economic
consideration prevents such systems as TCAS, from being
5 adopted by the great majority of the general aviation
industry.

Moreover, TCAS equipment requires complex on board
computers in conjunction with radio direction finding
equipment. Since TCAS equipped aircraft are capable of
10 interrogating all other aircraft in close proximity, the
result is that a large number of interrogations will occur
in high density air space. Eventually, the radio
transmission media will become saturated thereby rendering
both TCAS and secondary surveillance radar inoperative.

15 Even when working optimally, the TCAS and other
collision avoidance systems provide only a transponder code
assignment for identification, gives only relative heading
information and if properly equipped, altitude information.
In addition, the entire system is interrogation dependent.

20 In contrast to the previously available collision
avoidance systems, the present invention makes use of
existing ground based or satellite based equipment which
has already been widely accepted, rather than requiring new
dedicated equipment. Moreover, the present invention
25 provides navigational aid and emergency location functions
not contemplated in previously available systems.
Importantly, the collision avoidance, navigation aid, and
emergency location functions are all provided economically
and thus the necessary equipment can be installed on board
even small privately owned aircraft. Still further, the
30 present invention can be applied in space, air, land, and
sea craft and provide collision avoidance, navigation, and
emergency location functions in nearly every environment,
including IFR conditions.

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The present invention is able to achieve its great advantages over the previously available systems by utilizing one of the existing position determining systems, or their equivalent, that is now available or currently being implemented. For example, using the LORAN system a craft, or in the case of portable LORAN receivers an individual, can immediately obtain a position fix measured in latitude and longitude, in many areas of the world. Also, the GPS scheme, when fully implemented, will allow a position fix measured in latitude, longitude, and altitude, to be determined anywhere in the world with great precision. These existing position determining systems, and others when available, are used by the present invention to provide advantages not heretofore available in the art.

15

The described presently preferred embodiment of the invention utilizes the LORAN position determining system. While one form or another of the LORAN system has been known for many years, especially in the marine environment, it has recently gained world-wide acceptance among other types of craft operators, and particularly among aircraft operators. The LORAN system provides more useful navigational information than many other navigational instruments now in popular use, especially in the aviation environment. It has proven to be a highly reliable and safe system and has even been conditionally approved by the FAA for non-precision approaches to approved landing strips.

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The precision of the LORAN system generally ranges from 60 to 600 feet depending on the location of the craft in relation to the geometry of several widely spaced low frequency radio transmitters which provide the necessary position fixing signals. Because of the precision and versatility of the LORAN system, LORAN receivers are

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1 available which include computers, databases and displays
providing mapping and navigational aids to the operator of
a craft as the craft travels. For example, LORAN equipment
5 intended for aviation use is often provided with databases
that are updated monthly to provide all current airport
frequencies, runway orientation and length, airport
elevations, VOR, restricted and prohibited flight areas,
and other useful information.

10 Furthermore, some aviation LORAN receivers are able to
immediately locate several of the nearest airports in times
of emergency. LORAN equipment installed on aircraft is
able to compute ground speed, wind direction and speed,
tracking error, offer tracking and vertical navigation
15 advisories, and report minimum safe altitudes and degrees
of magnetic variation.

Excellent LORAN coverage is now available throughout
most of North America. LORAN coverage is partially
available in most other areas of the world including the
20 North Atlantic, the United Kingdom, Europe, the
Mediterranean Sea, North Africa, the Persian Gulf, Saudi
Arabia, and Japan. The relatively low cost and high
benefits of installing LORAN transmitters make the LORAN
system attractive to governments of both industrialized and
25 developing nations. Furthermore, upon its full implement-
ation, the GPS scheme will provide even greater benefits.
Since an existing position determining system is not
available everywhere, the term "operational range" will be
used to denote when a craft is in an area in which an
30 existing position determining system can be effectively
used.

Complete information concerning the LORAN system can
be obtained from the publications Melton, L., The Complete
Loran-C Handbook (Marine Publishing Co. 1986) and Sweeny,
D. J., "Learning About Loran," Radio-Electronics Magazine
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1 50-58, 69 (May 1987). Likewise, the GPS scheme may also be
used in accordance with the present invention. Further
information concerning GPS can be obtained from the
5 publications entitled "Introduction to Global Positioning,"
Civil Engineering 16-20 (Jan./Feb. 1987), Ashjaee, J.,
"Global Positioning System: Refined Processing for Better
Accuracy," Sea Technology 20, 22-25 (March 1986) and Enge,
P. K. et al. "Differential Operation of the Global
10 Positioning System," 26 IEEE Communications Magazine 48-60
(July 1988).

It will be appreciated that the present invention has
application in many different circumstances. Thus, as used
herein the term "craft" is intended to include any station-
15 ary object, any mobile animal or person, or any mobile
apparatus or vehicle. For example, land, sea and air craft
are specifically intended to fall within the meaning of the
term "craft."

Also, as used herein, the term "monitoring receiver"
20 means any device or apparatus invention which can monitor
the position of a craft which is transmitting position
information in accordance with the present invention.

The present invention comprises an apparatus and
method for announcing the position of a craft to a
25 monitoring receiver, either stationary or mobile, remotely
located from the craft. In one application, the present
invention can be used to track the position of one or more
craft at a stationary receiver. In another application,
the present invention can be used by one craft to track one
30 or more other craft. With the present invention in place,
as a first craft tracks all the other craft positioned
within a predetermined range of the first craft, and the
operator of the first craft is apprised of the position of
all the other craft, collisions between the craft can be
avoided.
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The presently preferred embodiment of the invention which is described herein is intended to be used primarily in the aviation industry. Those familiar with the aviation industry will appreciate that the problems of collision avoidance are particularly troublesome in today's crowded airspace. Adding to the problem of collision avoidance in the aviation industry are: the limited operator's field of vision in an aircraft cockpit; the speeds of the craft on a collision course provide very little time for a pilot to react and take corrective action; and an aircraft on a collision course may come from any direction in space.

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Also a universally useable or mandated collision avoidance system must be economically feasible for both small, modestly priced aircraft carrying just one or two persons and large multi-million dollar aircraft carrying hundreds of passengers and/or freight. Thus, at the current time, a most urgent need for the present invention lies within the aviation industry.

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Nevertheless, the present invention can be used as a position announcing and/or collision avoidance system in other demanding situations such as with water craft. Also, the present invention can be applied where a dispatcher needs to track the movement of a plurality of vehicles in a fleet, for example, motor trucks as their movements are coordinated for making deliveries and/or pickups, buses, trains, construction and other land based equipment.

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2. Detailed Description in Reference to Figures 1-4.

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In order to describe the presently understood best mode for making and using the present invention, the presently preferred embodiment of the present invention, as intended to be used in an aircraft environment will be described. As will be appreciated, the application of the present invention to air traffic monitoring and collision

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avoidance is one of, if not the most, demanding of the contemplated applications of the present invention because of, among other things, the speeds of the craft involved and the desirability to monitor three dimensional space as opposed to two dimensional space in the case of water and land craft.

Referring now to Figures 1A-1B, the preferred general method used by the system of the present invention will be explained.

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As shown at 10 in Figure 1A, the initial step of the transmit loop 9 is to obtain a position fix for one's own craft, also sometimes referred to herein as a first craft. The position fix is obtained using apparatus on board the craft. It is preferred that the position fix be obtained using an existing automated navigational system which will provide the position of the craft relative to a fixed reference, for example, latitude and longitude. This arrangement is in contrast to other collision avoidance systems which merely determine the distance between two craft and not their position relative to a fixed reference system. The LORAN system and the GPS system are among the preferred existing external automated navigational systems.

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While navigational systems which are capable of providing a position fix in two dimensions (e.g., LORAN) or three dimensions (e.g., LORAN in combination with an altitude encoder or GPS) are preferred, in some applications of the present invention it may only be necessary to obtain a position fix in one dimension or plane of space. For example, in one application of the present invention, an operator of an aircraft may only need to know if another craft is operating at the same altitude. While such information is only a portion of that which the described embodiment of the present invention can provide, it is of use to alert the operator of an aircraft. If

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another aircraft is operating within a close range at the same altitude, an operator of the aircraft should be warned that a collision with a another aircraft is possible if precautions are not taken.

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Thus, the position fix can be obtained from an altimeter only (for a one dimensional position fix), from a LORAN receiver (for a two dimensional position fix), from both a LORAN receiver and an altimeter or a GPS device (for
10 a three dimensional position fix). Other devices can also be used to obtain a position fix.

As indicated at step 12 in Figure 1, the position fix which was obtained in step 10 is encoded so that it can be carried by a radio frequency signal. In addition to the
15 position fix, an identification code (such as an aircraft registration number) and/or other messages are also encoded. It is preferred that the position fix and the identification code and other messages be digitally encoded so that they can be transmitted at a relatively high baud
20 rate as will be described in detail below.

In the United States, the radio frequency allocation of 1.6 Gigahertz has been reserved for aviation use. Thus, it is presently preferred, but not required, to utilize the 1.6 Gigahertz frequency allocation. Since all aircraft
25 utilizing the present invention preferably utilize the same frequency, step 14 provides that any conflicting radio frequency signals are listened for.

One of the significant advantages of the present invention is that, as opposed to previously available
30 collision avoidance systems, a craft transmits its own position fix and identification code information without being interrogated.

Since many craft may be using the described embodiment of the present invention, all using just one or a few radio
35 frequency allocations, avoidance of conflicting radio

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frequency signals is necessary. In use, some conflicts may occur in the described embodiment in areas where craft are highly concentrated. In the described embodiment, the position fix and identification code information is regularly and repeatedly transmitted. Thus, if an attempt at transmitting the position fix and identification code is postponed or "walked on" by another transmission, the information will be repeated in a short period of time.

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One preferred arrangement for preventing interference between conflicting radio frequency signals is to first listen for conflicting signals, as at step 14, and if a conflicting signal has existed, then wait a random period of time after the detection of a conflicting radio frequency signal, as at step 15. The length of the random period of time can be, for example, derived from the registration number of the aircraft, a random generation, or some other means. Alternatively, after the detection of a conflicting radio frequency signal, a predetermined period of time may be waited before transmission.

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Additional details concerning the settlement of a conflict between radio frequency signals can be devised by those skilled in the art and further information concerning the preferred example is provided later in this disclosure. It will be understood that various schemes, including the use of scanned multiple frequencies (spread spectrum technology), higher transmission rates, and other non-interrogation schemes, can be devised and used with the present invention.

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At step 16 in Figure 1, the radio frequency signal carrying the position fix and identification code information is transmitted and the pilot's own craft and relative bearing are displayed at step 17. The system then waits at step 19 for the transmit timer to expire, before re-entering the loop for another transmission.

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Whether it is desired to avoid collisions between multiple craft or to track a single craft, it is nearly always desirable to have the radio frequency signal received only within a limited range. Thus, the radio frequency signal is of limited strength. For example, when functioning to avoid collisions between aircraft, the area of interest is generally a radius of between from about 1 to about 30 miles around one's own aircraft or around the airport. Nevertheless, in some cases, such as in the case of land or sea craft, the range of interest may be greater or lesser than that which is desirable for aircraft.

The radio frequency signal carrying the position fix, identification code information, and other messages, is of limited power so that only the radio frequency signal transmitted from craft within a predetermined range will be received. This reduces the number of radio frequency signals which conflict with one another, allowing a large number of aircraft to be simultaneously operating within a predetermined range. Other embodiments of the present invention can be fabricated which allow a greater number of craft to be simultaneously operating within the predetermined range.

Preferably, the radio frequency signal from each of the aircraft is transmitted, and received, omnidirectionally. Since position information is encoded within the radio frequency signal, and not derived from the signal strength or direction, complicated antenna arrangements are not necessary with the present invention. As will be appreciated, in the case of aircraft the term "omnidirectionally" is intended to include three planes of space while in the case of land or water craft, the term "omnidirectionally" generally need only include horizontal two dimensional planes surrounding the craft.

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As indicated at step 18 of receive loop 13 in Figure 1B, the radio frequency signals for other craft are transmitted and are received at a craft or another location which is equipped with a monitoring receiver in accordance with the present invention. The receiving location may be a ground location which is tracking one or more craft. The radio frequency signals are decoded, as indicated at step 20, and the position fix and identification code information is displayed at step 21.

Once the position information has been extracted from the radio frequency signals, the position of all the other craft within the predetermined range can be displayed as represented at step 21 in Figure 1B. As each craft regularly transmits its own position, it is possible to calculate all relative essential elements of heading, speed and distance of each craft which can then be displayed. In the case of craft on a collision course, the projected point of impact and time of impact can be calculated and displayed while the operators of the craft are alerted to the danger and given appropriate advisories. While it is not always necessary, it is preferred that an identification code for each craft be transmitted. The transmission of a craft identification code and its current operating communication radio frequency simplifies the organization of incoming data and enhances safety by providing a craft identification for two-way radio communication.

Included in step 21 of displaying the position of all craft transmitting a radio frequency signal within the predetermined range is preferably the step of displaying the position of one's own craft. Also, it is preferable to issue a collision alert if a collision is possible between two craft on their present headings. Also, since, one's own position fix has already been determined, it is pos-

1 sible to display the position of one's own craft against a
map superimposed on the display. Data to create such maps
can be provided by databases as are available in the art.

5 Preferably, each of the craft may be provided with a
recording device which will provide a non-volatile record
of all position and identification information which is
received, and if desired the position information of one's
own craft. Thus, if an aircraft were to become disabled
10 and go down, the radio frequency transmissions would
continue to transmit the position and identification of the
craft to be observed by other craft. If the apparatus did
not survive a crash, any properly equipped craft within
range recording all received position and identification
15 information and the last transmitted radio frequency signal
from the downed aircraft would provide precise information
of the location information of the crash site. With either
alternative, the present invention can be used as an
emergency location system that will supply more precise
20 information than that commonly available on the ELT
(Emergency Location Transmitter) system in current use.

Referring next to Figure 2, a primary aircraft 30 is
represented at the center of a sphere 36. The sphere
(which is not to scale) represents the predetermined range
25 in which the radio frequency signal broadcast from the
primary aircraft 30 can be received by other aircraft also
carrying the system of the present invention. Thus, the
operator of a secondary aircraft 32, being within the
predetermined range, will receive a collision alert if the
30 two craft are on a collision course. Alternatively,
another secondary craft 34 will not be made aware of the
position of the other two aircraft until it comes within
the predetermined range represented by sphere 36. A ground
based monitoring receiver 38 is also represented in Figure
35 2. The ground based monitoring receiver can function as an

1

air traffic control station as the craft come within range.

Referring next to Figure 3, a block diagram of the presently preferred embodiment of the present invention is provided. The high level functional blocks include: a position determining block 100; an interface controller block 102; a radio frequency block 104; an antenna 106; and a control block 108. In most of the functional blocks, additional components are represented. The components represented in Figure 3 are generally included on board a craft or can be located at a stationary location.

Represented within the position determining block 100 are a latitude/longitude position determining device 100A and an altitude determining device 100B. It will be appreciated that many aircraft already include appropriate latitude/longitude position determining devices and an altitude determining device and thus the components represented within the position determining block 100 may not be included in all embodiments of the present invention. It is one of the advantages of the present invention that the existing equipment already provided on many aircraft can be used in conjunction with embodiments of the present invention. In the case of a water or land craft, the inclusion of only a latitude/longitude device is generally all that is necessary.

The presently preferred latitude/longitude position determining device is a LORAN-C receiver available from ARNAV, a subsidiary of Flight Dynamics, Inc., of Portland, Oregon and referred to as Model R-50. The described LORAN receiver provides many desirable features as well as the ability to communicate with other devices via the industry standard RS-232 communication protocol.

The presently preferred altitude determining device is an altimeter available from ACK Technologies, Inc. of San Jose, California, Model A-30. Information concerning

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interfacing the indicated altimeter to other components is available from the manufacturer.

5 The devices included in the position determining block 100 are a preferred example of a means for determining, on board a craft, the craft's position using an existing external navigation system. The means for determining the craft's position can include, depending upon the particular application of the invention, devices for determining the
10 craft's position in one, two, or three dimensions (or planes) of space.

 The present invention includes means for encoding the position of the craft, which can also preferably encode an identification code for the craft, so such information can
15 be carried by a radio frequency signal. The presently preferred example of a means for encoding the position and identification of the craft is the interface controller 102 represented in Figure 3.

 The identification code may be an aircraft
20 registration number or any other number unique to the craft. While it is not essential to encode and transmit the craft identification code with the radio frequency signal, it is desirable to do so.

 Still referring to Figure 3, the interface controller
25 102 communicates with the devices of the position determining block 100 by way of communication ports included in the devices. The presently preferred example of the interface controller 102 is a system available from Enduratek Corporation of Salt Lake City, Utah and referred
30 to as the Data-V-Com system. Complete information concerning the Data-V-Com system can be obtained from the publication "Mobile Data Terminal System Operations Manual" available from Enduratek Corporation.

 The interface controller 102 system performs data
35 encoding and preparation functions needed to transmit the

1

digital information via a radio frequency signal and functions as the presently preferred example of a means for encoding the position of the craft into information which can be carried by a first radio frequency signal and a means for decoding the other craft's position from a radio frequency signal. Other devices performing similar or equivalent functions are intended to be included within the scope of the means for encoding included within the present invention. The designated interface controller 102 also functions as the presently preferred example of a means for decoding the position and identification information received from other craft.

The radio frequency block 104 includes a modulator 104A, a radio transmitter 104B, an antenna duplexer 104C, a radio receiver 104D, and a demodulator 104E. The components of the radio frequency block are preferably included in a radio frequency transceiver capable of operating in the microwave band containing 1.6 Gigahertz. One presently preferred transceiver which operates in the VHF band is available from Icom, Model No. IC-A20. It will be appreciated that devices other than the designated transceiver, and frequencies other than 1.6 Gigahertz, for example any appropriate radio frequency may be used within the scope of the present invention.

Also represented in Figure 3 is an antenna 106, which may comprise one or more individual antennas or antenna elements, and which is preferably one that will provide an omnidirectional radiation pattern. It is desirable that the radiation pattern and the reception pattern both be omnidirectional. The antenna duplexer 104C serves to isolate the radio transmitter 104B from the radio receiver 104D while allowing both to use the same antenna.

Still referring to Figure 3, a modulator 104A functions to modulate the carrier radio frequency wave with

1

the craft position and identification information encoded by the interface controller 102. A demodulator 104E similarly functions to extract the position and identification information from any radio frequency signal which is received and to pass the same onto the interface controller 102. The modulator 104A and demodulator 104E may be embodied in a device commonly referred to as a modem, which is available in the art.

10

The components represented within the radio block 104 and the antenna 106 are the presently preferred example of a means for transmitting the first radio frequency signal and a means for receiving a radio frequency signal. The interface controller 102 communicates with, and operates, the components of the radio frequency block 104 by way of connectors and cables customarily included on radio frequency transceivers as will be understood by those skilled in the pertinent art.

15

The interface controller 102 represented in Figure 3 also communicates with a computer 108A which is included in the components of the control block 108. The computer 108 is preferably one which is equivalent to an IBM model PC AT. One of the many commercially available portable models (generally referred to as "Lap Tops") of the specified equivalent computer can also be used. The computer 108A and the interface controller 102 communicate with each other by way of the customary connectors and protocols (such as the RS-232 protocol) which are well known to those skilled in the art.

20

25

30

Included in the control block 108 is a display 108B. The display 108B may be integral with the computer 108A or may be separate therefrom. The display is preferably used to provide a graphical representation of the position of the craft which are within the predetermined range of the monitoring craft or receiver.

35

1 Thus, the operator of the craft can observe on the display
the position of both his own craft (desirably in the center
of the display) and the position of all other craft
5 surrounding his craft within the predetermined range.

One preferred embodiment of the display would
incorporate the use of a head-up display to display not
only collision avoidance information, but to also aid in
proximity reporting, navigation under IFR conditions,
10 coordinated descence into controlled and uncontrolled
airports and landing strips, and other relevant
information, and to project these pertinent images in a
forward view mode into the wind screen and line of the
actual and preferred flight path.

15 It will be appreciated that some embodiments of the
present invention may provide additional benefits if the
display is one which not only provides high resolution in
two dimensions, but one which is also suitable for
displaying three dimensions, i.e., a display wherein depth
20 can be represented by either using a three dimensional
graphics mode or by decreasing intensity as a position
recedes from the viewer and greater intensity as the
position moves toward the viewer. Altitude information as
well as indicators showing whether or not aircraft are
25 climbing or descending can also be depicted on the display.

In the case of the present invention as applied to the
aviation industry, it is desirable that the position of
aircraft other than those in the same horizontal plane be
displayed. Namely, the display 108B should provide
position information of a plurality aircraft vertically
30 displaced from the monitoring craft (i.e., differing
altitude) as well as in the same horizontal plane (latitude
and longitude). Depending upon the particular embodiment
of the invention, the display 108B, or all of the
components represented in radio block 108, function as a
35

1 means for displaying a craft's position as defined by the
present invention. Other devices and arrangements
performing similar or identical functions are intended to
5 be considered equivalent to the described structures.

Also represented in the control block 108 are input
devices 108C. Input devices 108C can include a keyboard
(which may be integral with the computer 108A) or other
general purpose or dedicated input devices. An
10 audio/visual alarm 108D is also represented in control
block 108. The audio/visual alarm can be integral with the
computer 108A or can be one of several dedicated alarm
devices intended to apprise the operator of a craft of a
potential collision or other situation requiring attention.

15 A recorder 108E is also provided in the control block
108 to make a non-volatile recording of selected data
received by the computer 108A. Preferably, the recorder
108E is used to periodically log the position of all craft
within the predetermined range. Thus, if a monitored craft
20 becomes disabled and stops transmitting its radio frequency
signal carrying position information, the last recorded
position fix logged in the recorder 108E of any craft or
observation station within the predetermined range can aid
in the location of a disabled craft.

25 Furthermore, if a craft continues to transmit its
radio frequency signal with its own position fix after
becoming disabled, it will function as an emergency
location device and will assist search and rescue crews in
the rapid location of the disabled craft. In some
embodiments of the invention, the radio frequency signal
30 can carry, in addition to position and identification
information, a distress signal as well as other messages to
indicate a need for emergency assistance and even describe
what type of emergency assistance is required at the
disabled craft.

35

1 If desired, the components of the control block 108,
the interface block 102, and the reception components of
the radio frequency block 104 can be used as a monitoring
5 receiver. For example, a monitoring receiver can be used
as a ground control station to monitor the airspace
surrounding an airport. In the case of small airstrips or
airports in developing areas, the present invention can be
adapted to provide both airborne craft and ground control
10 personnel the information necessary to coordinate air
traffic. This application of the embodiment of the
invention would allow for the system's use as a standard
ATC system exclusive of expensive radar installations, and
at extremely low cost.

15 It will be appreciated that while the described
embodiment is the presently best known mode for carrying
out the invention, those skilled in the pertinent art will
understand that other components may be used to carry out
the invention. For example, the functional blocks
20 illustrated in Figure 3 may be combined into a few, or just
one, devices housed in a single enclosure. Moreover, as
the art progresses, the inventive concepts of the present
invention may be embodied in devices not yet available but
carrying out functions equivalent to those described in
connection with the preferred embodiment. All such
25 alternative embodiments of the invention are intended to
fall within the scope of the present invention.

Provided in Figures 4-1 through 4-11 is a more
detailed flow chart describing the steps carried out by the
above-described embodiment. In these figures, the boxed
30 letter designations indicate the interconnections between
the portions of the flow chart which are divided between
figures.

The flow chart provides a description of the high-
level functions carried out principally by the interface
35

1 controller 102 represented in Figure 3. In the presently
preferred embodiment of the present invention, the
interface controller 102 is implemented by the above
described Data-V-Com system.

5 It will be appreciated that the flow chart represented
in Figures 4-1 through 4-11 represents just one preferred
example of the programming steps that can be used to carry
out the present invention and those skilled in the art will
10 be able to devise other embodiments of the present
invention using the teaching contained herein. Also, as
will be appreciated after an examination of Figures 4-1
through 4-11, the Lap Top (a portable computer which
functions as the computer 108A represented in Figure 3)
15 functions principally to display the data presented to it
by other components and to provide input and output
functions with a human user. The text contained in the
dashed boxes are included to improve the clarity of the
flow chart and do not represent steps in the method.

20 The flow chart contained in Figures 4-1 through
4-11 is divided into several principal routines as
indicated below.

Flow Chart Routine

Figure Nos.

Initialization
Radio
25. Loran
Altimeter
Lap Top

Figs. 4-1 through 4-4
Figs. 4-5 through 4-6
Fig. 4-7
Fig. 4-8
Figs. 4-9 through 4-11

Further information concerning each of the routines
indicated above is provided in the Glossaries set forth
30 below.

1

A. Initialization Routine Glossary.

	Ref. No.	Label	Description
5	200	START	This is the beginning of the program. When the micro-processor is reset via hardware or software it is vectored to this point. At START, the Stack Pointers, Interrupt disabling and various other Housekeeping chores are performed.
10	202	SELFTTEST	This is the beginning of the Selftest Module. At this point the Diagnostic Terminal will display that Selftest has started. Also at this point Selftest Interrupts will be set up and enabled.
15	206	RAM TEST PASS	The RAM (Random Access Memory) test is run. The RAM test writes data found in a ROM table to each RAM address. If the same data that was written is read back, the program continues through the table until the data 00H is written. This signifies the end of the test and leaves all RAM cleared and ready for use. If the test fails at any point the data read, data written and the address are saved and reported back to the Diagnostic Terminal. The RAM should be replaced at the address reported if failure occurs.
20			
25	208	SET RAM TEST FAIL BIT	The Selftest Status is sent to the Lap Top and to other Aircraft via the Radio. If this bit is set it means that the RAM Test Failed and all data is unreliable.
30	210	ROM TEST PASS	All Used ROM (Read Only Memory) is added and the sum must equal zero. The Check Sum Adjust Byte at 3FFFH ensures that the sum (without carry) is zero. If the sum is not zero the test fails and ROM should be replaced. The test failure status and the erroneous check sum are reported to the Diagnostic Terminal.

35

1

212 SET ROM The Selftest Status is sent to the Lap
TEST FAIL Top and to other Aircraft via the
BIT Radio. If this bit is set it means
that the ROM Test Failed and all data
is unreliable.

5

214 LAP TOP The USART (Universal Synchronous
INTER. Asynchronous Receive Transmit) 8051 is
PASS Software reset and the MIF (Mode
Instruction Format) set up. Status is
then checked and verified.

10

216 SET LAP The Selftest Status is sent to the Lap
T O P Top and to other Aircraft via the
INTERFACE Radio. If this bit is set it means
FAIL BIT that the Lap Top Communication could be
unreliable.

15

218 I/O TEST The PIA (Peripheral Interface Adapter)
PASS 8155 is initialized for the proper
mode, which ports are Inputs and which
are outputs and the Baud rate Clock set
up. Outputs are initialized. Status
is then checked and verified.

20

220 S E T The Selftest Status is sent to the Lap
INPUT/ Top and to other Aircraft via the
OUTPUT Radio. If this bit is set it means
FAIL BIT that the PIA is unreliable. The PIA
interfaces mainly with the Altimeter.

25

222 R A D I O The USART (Universal Synchronous
INTER Asynchronous Receive Transmit) 8051 is
PASS Software reset and the MIF (Mode
Instruction Format) set up. Status is
then checked and verified.

30

224 SET RADIO The Selftest Status is sent to the Lap
INTERFACE Top and to other Aircraft via the
FAIL BIT Radio. If this bit is set it means
that the Radio Communication could be
unreliable.

35

- 1
226 A D D Each System has its own Aircraft
AIRCRAFT Identification Via the Diagnostic
ID Terminal the Aircraft Identification is
put in NonVolatile Memory or EEPROM.
5 (Electrically Erasable Read Only
Memory). This Identification number
will not be lost if the system is reset
or powered down. When Selftest is run
the system can sense that the Terminal
is attached and allow the user the
option of changing the Aircraft
Identification This block asks the
10 question, Do You Want to Enter Aircraft
Identification?
- 228 G E T This block Prompts the Terminal, for
AIRCRAFT the Identification, Error Checks it and
ID buffers it.
- 15 230 E N T E R This block enters the buffered aircraft
AIRCRAFT Identification into EEPROM.
ID
- 20 232 PUT IN Because the preferred embodiment of the
R A N D O M present invention is polite (will not
X M I T transmit when another signal is already
TIMER present on the frequency). To eliminate
various systems transmitting
simultaneously, each system will have
different wait times before transmit-
ting after a frequency has cleared.
This random wait time is determined by
the system Aircraft Identification in
the preferred embodiment.
- 25 234 T O G G L E Changes the printer status.
P R I N T E R
S T A T .
- 30 236 C H G To enable someone to monitor the entire
P R I N T E R system there is a port for a printer or
S T A T some other type of monitor. At this
time the Diagnostic Terminal can be
used for changing the Status of the
Printer or Monitor. The Status is kept
in NonVolatile ROM or EEPROM so that if
the System is powered down or reset
that status will not change.
- 35 240 I N I T I A - Pointers such as the Input and Output

1		L I Z E POINTERS TIMERS ETC.	Pointers for the Rotating buffers used for the Lap Top Interface are set up at this time.
5	242	S E T ALTIMETER DATA TO 9's	At this point in the Program it is not known if the Altimeter is functional or not, especially since the Altimeter does not function for several minutes after it is powered up. So that any data present is not mistaken for good Altimeter Data all 9's are inserted in the Altimeter use area.
10	244	SET LORAN DATA TO 9's	At this point in the Program it is not known if the Loran Receiver is functional or not, especially since the Loran Receiver must be initialized manually to send the proper information at the proper baud rate, transmit rate, and so forth. To ensure that any random data already present is not mistaken for good data, all 9's are inserted in the Loran Longitude and Latitude buffers.
15			
20	246	SET # MESSAGE FLAG	The # message Flag is set so that when the system is fully initialized and functional, the # message will be sent to the Lap Top Computer.
25	250	EXECLP	This is the exit point for initialization that has been performed heretofore and the loop point for the rest of the program. When the rest of the program has completed it will come back to this point and begin again at this point.
	252	C A L L RADIO	The Radio Module (See step 276, Figure 4-5) is interfaced at this point.
30	256	C A L L LORAN	The Loran Module (See step 312, Figure 4-7) is interfaced at this point.
	260	CALL LAP TOP	The Lap Top Computer Module (See step 348, Figure 4-9) is interfaced at this point.

- 1
- 264 R E S E T. See step 266.
WATCH DOG
- 266 TRANSMIT- If the system is transmitting the watch
TING dog timer is not reset. This helps to
5 ensure that the system does not
transmit for too long a period. If the
watch dog is not reset every 1.1
seconds the system is reset, the
Program Counter goes to 0000H or the
Start.
- 10 268 C A L L The Altimeter Module is interfaced at
ALTIMETER this point.

B. Radio Routine Glossary.

- | Ref. No. | Label | Description |
|----------|--|--|
| 15 | 272 R A N D O M
T I M E R E X P | After the frequency has been busy this timer must expire before transmitting. (See steps 232 (Figure 4-2) and 278 (Figure 4-5). |
| 20 | 274 ' T '
R E L O A D
V A L U E N O N
O ? | |
| 25 | 276 R A D I O | This is the entrance to the RADIO module. This module handles all the communication to/from the Radio. All communication to other aircraft is via the Radio. |
| 30 | 278 R E S E T
X M I T
T I M E R | The value used to reset the XMIT timer is the value obtained from the 'T' message from the Lap Top Computer. (See steps 274 (Figure 4-5), 350 (Figure 4-9) & 376 (Figure 4-10). |
| 35 | 280 C H A N N E L
C L E A R | Because the system is polite (See step 232 (Figure 4-2)). It will not transmit unless the channel is clear. The Carrier Active Sense (CAS) is checked at this point to see if the frequency is clear or not. |

- 1
- 282 X M I T The location message for this aircraft
TIMER EXP must be transmitted to the other
aircraft at a rate determined via a 'T'
message from the Lap Top Computer. If
the 'T' message time is 0 then (which
is what it is upon initialization) then
the message is not transmitted at all.
- 5
- 286 GET THIS The Aircraft Identification is read
AIRCRAFT from EEPROM and stored in the Radio
ID Transmit buffer. (See steps 230, 228
(Figure 4-2), & 226).
- 10
- 290 R E S E T The Random timer must be reset with the
R A N D O M value determined from the Aircraft
TIMER Identification (See steps 232 (Figure
4-2), 280 & 372 (Figure 4-5)).
- 15
- 292 GET LORAN The most recent data from the Loran
LAT. LON. Receiver is placed in the Transmit
DATA buffer. (See steps 292 (Figure 4-6),
314 & 320 (Figure 4-7)).
- 20
- 296 MESSAGE By examining the input buffer it can be
RECEIVED? determined if a message has been
received.
- 20
- 298 CHECK SUM Each byte of the message is added
CORRECT w/carry and it is determined if the
message is error free or not.
- 25
- 300 P U T The message received above is
MESSAGE rebuffered into the large rotating Lap
IN LAP Top Computer Buffer for transmittal to
T O P the Lap Top Computer.
BUFFER
- 30
- 302 GET LORAN This byte indicates the Loran Status.
STATUS (See step 330 (Figure 4-7)). The Loran
Receiver transmits in addition to the
Latitude and Longitude the Status of
the Receiver.
- 35
- 304 S E T This flag tells the Lap Top Module that
L A P T O P a message is ready to go to the Lap Top
MESSAGE Computer.
R E A D Y
FLAG

1	306	GET DATA V - C O M STATUS	The Data-V-Com Status includes not only the Selftest status, (See steps 208, 212, 216, 220 & 224 (Figures 4-1 & 4-2)) but also status as to how current the Loran Information is.
5	308	G E T MESSAGE CHECKSUM	After Concluding with step 306 (Figure 4-6) the message is formatted and the Check sum is calculated by adding up each byte (w/carry).
10	310	O U T P U T MESSAGE	The message formatted above is output (AFSK) via the USART. An attack delay (a period of no data to enable the transmitter to stabilize) as well as a time delay at the end is necessary.
15	C. Loran Routine Glossary.		
	Ref. No.	Label	Description
20	312	LORAN	This is the Entrance Point for the Loran Module. This module handles the interface with the Loran receiver. Besides receiving the Latitude and Longitude it also saves the Loran Status and keeps track of if an update occurs between Message transmissions to other aircraft and to the Lap Top.
25	314	S A V E LATITUDE	The Latitude less the spaces is saved. (See step 318 (Figure 4-7)). A flag is set so that it can be determined that data was received for Lat. and Lon. so that when processed will be data that is compatible.
30	316	LATITUDE	Checks for LAT (See step 318 (Figure 4-7)) in message coming in from Loran Receiver.
35	318	MESSAGE COMING IN?	The entire message from the Loran Receiver is not saved. If a message is coming in the program looks for LAT for Latitude and LON for longitude and SD for Loran Status. If these labels are found the data less the spaces is saved.

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- 320 S A V E STATUS The Loran Status is saved for transmission to other Aircraft, as well as the Lap Top Computer. This makes it possible to know the accuracy of the Loran as well as other pertinent information. (See steps 388 (Figure 4-11) & 302 (Figure 4-6)).
- 322 LONGITUDE ? Checks for LON (See step 318 (Figure 4-7)) in message coming in from Loran Receiver.
- 324 ALL DATA RECEIVED? See step 318.
- 326 PUT LAT. IN LAPTOP BUFFER The message received above is rebuffered into the large rotating Lap Top Computer Buffer for transmittal to the Lap Top Computer.
- 330 S A V E STATUS See step 320.
- 332 L O R A N STATUS? A flag is set for each of the 11 different types of status if that particular status is read from the Loran Receiver.
- 334 PUT LON. IN LAPTOP BUFFER See step 326.
- 336 PUT LORAN STATUS IN LAPTOP BUFFER See step 332.

D. Altimeter Routine Glossary.

30

Ref. No.	Label	Description
338	ALTIMETER	This is the Entrance point to the Altimeter handler. It reads the 11 Discrete inputs and decodes the data to an ASCII altitude. If the altitude is bad a 998 is output.

35

- 2
- 340 G E T Reads the 11 Discrete inputs from the
DISCRETE Altimeter. If some are not used the
I N P U T S program is modified so that they are
(11) assumed to be most significant and low.
- 342 GET ALT. The data is deemed good and saved for
F R O M messages to the Lap Top and to other
TABLE Aircraft.
- 344 I N P U T A look up table is used to decode the
DATA IN 11 inputs to a three digit altitude
TABLE reflecting 100's of feet. If the table
reflects 998 then the data is deemed to
be bad and is rejected.
- 346 GET '998' The data in the table was bad, so
instead of unreadable data a '998' is
used to reflect the error.

15 E. Laptop Routine Glossary.

Ref. No.	Label	Description
348	LAPTOP	This is the input to the module. This module handles all communication to/from the Lap Top Computer.
350	PUT '#' I N MESSAGE	Put the '#' is the output buffer for this particular message to the Laptop.
352	CLEAR '#' FLAG	See step 354 (Figure 4-9).
354	'#' FLAG SET?	This flag indicates that a # Message must be sent to the Lap Top Computer. This flag is set only during Initialization. (See step 246 (Figure 4-3)).
358	GET THIS AIRCRAFT ID	The Aircraft Identification in Nonvolatile memory (EEPROM), is put in the transmit buffer to go to the Lap Top Computer. (See step 228 (Figure 4-2)).

- 360 G E T MESSAGE FROM OTHER AIRCRAFT The message that was received from another aircraft via. the RADIO module is rebuffed and sent to the Lap Top Computer.
- 362 'O' FLAG SET? The 'O' determines if messages from other Aircraft are accepted or not. If the Flag is set, which must occur when a 'O' message is received from the Lap Top Computer, (See step 378 (Figure 4-10)) then other aircraft messages are accepted.
- 364 G E T SELFTEST STATUS The Selftest Status (See steps 208, 212, 216, 220 (Figure 4-1) & 224 (Figure 4-2)) is put in the buffer to be transmitted to the Lap Top Computer.
- 366 RESET 'L' TIMER The time value received from the Lap Top Computer, (See step 390 (Figure 4-11)) is used to reset this timer.
- 368 'L' TIMER EXP The 'L' timer determines how often the Location message for this aircraft is sent to the Lap Top Computer. If the value is set at 0, which occurs on initialization, it is not sent at all. The value that the 'L' timer is set to is determined by the 'L' message received from the Lap Top Computer. (See step 390 (Figure 4-11)).
- 372 GET THIS AIRCRAFT ID The Aircraft Identification in Nonvolatile memory (EEPROM), is put in the transmit buffer to go to the Lap Top Computer. (See step 228 (Figure 4-2)).
- 376 GET THIS LONGITUDE LATITUDE This information is obtained from the Loran module. (See steps 314 & 320 (Figure 4-7)) and is put in the transmit buffer to go to the Lap Top Computer.
- 378 " O " MESSAGE? Is the incoming message from the Lap Top Computer an 'O' message? If so the 'O' flag is set. (See step 362 (Figure 4-10)).

2

380 SET "0" See step 378 (Figure 4-10).
FLAG

3

382 GET THIS This information is obtained from the
ALTITUDE Altitude module. (See step 342 (Figure
4-8)) and is put in the transmit buffer
to go to the Lap Top Computer.

10

384 " T " Is the incoming message from the Lap
MESSAGE? Top Computer a 'T' message? (See steps
274 & 282 (Figure 4-5)). If so the 'T'
Reload value is saved. This value
determines how often the Radio
Transmits the Location of the Aircraft
to other Aircraft.

386 GET "T" See step 384 (Figure 4-11). This value
RELOAD is used at step 372 (Figure 4-5).
VALUE

15

388 GET THIS This information is obtained from the
LORAN Loran module. (See step 330 (Figure 4-
STATUS 7)) and is put in the transmit buffer
to go to the Lap Top Computer.

20

390 " L " Is the incoming message from the Lap
MESSAGE? Top Computer an 'L' message? (See
steps 368 (Figure 4-10) & 392 (Figure
4-11)). If so the 'L' Reload value is
saved for use at step 366 (Figure 4-
10).

392 GET "L" See step 390 (Figure 4-11). This value
RELOAD is used at step 366 (Figure 4-10).
VALUE

25

394 GET After concluding with step 388 (Figure
CHECKSUM 4-11) the message is formatted and the
Check sum is calculated by adding up
each byte (w/carry).

30

396 " R " Is the incoming message from the Lap
MESSAGE? Top Computer an 'R' message? If so the
program is vectored through software to
the start address. (See step 276
(Figure 4-5)).

398 OUTPUT The message formatted above is output
MESSAGE via the USART to the Lap Top Computer.

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3. Summary.

In view of the foregoing, it will be appreciated that the present invention provides a system and method for announcing the position of a craft to a remote receiver such that the position of the craft can be continuously monitored and collisions with other craft avoided. The present invention also provides a system and method for collision avoidance which may be used in addition to, and without interference with, preexisting collision avoidance systems.

It will be further appreciated that the present invention also provides an emergency location system for distressed or disabled craft and a collision avoidance system which can be economically implemented in the general aviation industry. Still further, the present invention provides a system and method which allows the operator of a first craft to monitor the position of a plurality of other craft within a predetermined range of the first craft and to be alerted of a potential collision as early as possible.

The present invention also provides a system and method of monitoring craft proximity spacing, a critical function, while operating within the flight sector system in high density areas and while transitting or making approaches in VFR and IFR controlled airspace. Further, the system and method provide a similar function in the marine environment, particularly under adverse weather conditions and high density mooring or docking maneuvers.

Even further, after consideration of the foregoing, it will be understood that the present invention provides a system and method for announcing the position of any craft to other craft which are within a predetermined range which is reliable and which does not distract an operator of a craft from other duties unless operator attention is

1 necessary. Moreover, the operator of a first craft is
allowed to continually monitor the positions of a plurality
of other craft within a predetermined range. Even further,
5 the present invention provides a system and method of
tracking the position of one or more craft within a
predetermined range of a location anywhere on the earth
such as at a remote airstrip or allows the position of each
of a plurality of craft belonging to a fleet to be tracked.
10 Still further, the present invention provides a collision
avoidance system which does not become saturated in areas
of dense traffic and which readily makes a permanent record
of the movement of any craft within a predetermined range
of a monitoring receiver.

15 The present invention may be embodied in other
specific forms without departing from its spirit or
essential characteristics. The described embodiment is to
be considered in all respects only as illustrative and not
restrictive. The scope of the invention is, therefore,
20 indicated by the appended claims rather than by the
foregoing description. All changes which come within the
meaning and range of equivalency of the claims are to be
embraced within their scope.

What is claimed is:

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2. 1. A method for announcing the position of a first
aircraft at a first position, the first position being
within airspace containing a plurality of other aircraft,
5 to a receiver located at a second position not farther than
a predetermined range from the first position, the method
comprising the steps of:

(a) determining on board the first aircraft the
position of the first aircraft relative to a fixed
10 reference;

(b) encoding the position of the first aircraft
so that the position of the first aircraft can be
carried by a first radio frequency signal;

(c) avoiding conflicts with any radio frequency
signals present in the airspace which conflict with
15 the first radio frequency signal;

(d) transmitting the first radio frequency
signal carrying the position of the first aircraft
from the first aircraft;

(e) receiving the first radio frequency signal
transmitted from the first aircraft at the second
20 position;

(f) decoding the position of the first aircraft
from the first radio frequency signal; and

(g) monitoring the position of the first
aircraft within the airspace at the second position so
25 that the position of the first aircraft within the
airspace is known relative to the fixed reference.

30 2. A method for announcing the position of a first
aircraft at a first position to a receiver located at a
second position as defined in claim 1 wherein the step of
determining the position of the first craft comprises the
step of receiving a LORAN signal.

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3. A method for announcing the position of a first
aircraft at a first position to a receiver located at a
second position as defined in claim 1 wherein the step of
5 determining the position of the first craft comprises the
step of receiving a GPS signal.

4. A method for announcing the position of a first
aircraft at a first position to a receiver located at a
10 second position as defined in claim 1 wherein the fixed
reference exists both within the airspace and without the
airspace.

5. A method for announcing the position of a first
15 aircraft at a first position to a receiver located at a
second position as defined in claim 4 wherein the step of
determining the position of the first aircraft comprises
the step of determining the position of the first aircraft
in reference to the fixed reference.

20 6. A method for announcing the position of a first
aircraft at a first position to a receiver located at a
second position as defined in claim 5 wherein the step of
determining the position of the first aircraft further
25 comprises the step of determining the altitude of the first
aircraft..

7. A method for announcing the position of a first
aircraft at a first position to a receiver located at a
30 second position as defined in claim 1 or 5 wherein the step
of encoding the position of the first aircraft comprises
the step of encoding the position of the aircraft into a
digital pulse train.

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1 8. A method for announcing the position of a first
 aircraft at a first position to a receiver located at a
 second position as defined in claim 7 wherein the step of
5 encoding the position of the first aircraft further
 comprises the step of translating the position of the first
 aircraft into an audio signal.

 9. A method for announcing the position of a first
10 aircraft at a first position to a receiver located at a
 second position as defined in claim 1 wherein the step of
 avoiding conflicts with any conflicting radio frequency
 signals in the airspace comprises the step of listening for
 any conflicting radio frequency signals.

15 10. A method for announcing the position of a first
 aircraft at a first position to a receiver located at a
 second position as defined in claim 9 wherein the step of
 avoiding conflicts with any conflicting radio frequency
20 signals in the airspace comprises the step of waiting a
 period of time prior to transmission.

 11. A method for announcing the position of a first
 aircraft at a first position to a receiver located at a
25 second position as defined in claim 10 wherein the step of
 avoiding conflicts with any conflicting radio frequency
 signals in the airspace comprises the step of waiting a
 predetermined period of time prior to transmission.

30 12. A method for announcing the position of a first
 aircraft at a first position to a receiver located at a
 second position as defined in claim 10 wherein the step of
 avoiding conflicts with any conflicting radio frequency
 signals in the airspace comprises the step of waiting a
35 random period of time prior to transmission.

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13. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 or 10 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of transmitting a radio frequency signal in a non-interrogation manner.

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14. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in the frequency range from about and including the VHF band to about and including the SHF band.

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15. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in a substantially omnidirectional pattern.

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16. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of encoding the position of the first aircraft further comprises the step of encoding an identification code for the first aircraft so that the identification code can be carried by the first radio frequency signal and wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the identification code for the first aircraft.

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17. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 further comprising the step of repeating steps (a) through (g).

18. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 17 wherein the step of monitoring the position of the first aircraft comprises the step of repeatedly displaying the position of the first aircraft on a display as the aircraft changes position.

19. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 18 wherein the step of monitoring the position of the first aircraft further comprises the step of displaying the heading and the speed of the first aircraft on a display.

20. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of monitoring the position of the first aircraft comprises the step of displaying the relative position of the first aircraft on a display over a selected period of time.

21. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 further comprising the step of determining the location of the second position relative to the fixed reference and wherein the step of monitoring the position of the first aircraft comprises the

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1 step of displaying the position of the first aircraft and
the location of the second position.

5 22. A method of tracking the position of a first
craft by a monitoring receiver, the first craft and the
monitoring receiver being within a predetermined range of
each other, the method comprising the steps of:

10 (a) determining, internally to the first craft
using an external automated navigational system, the
first craft's position in at least one plane of space;

 (b) encoding the first craft's position in a
form which can be carried by a first radio frequency
signal;

15 (c) determining when the first radio frequency
signal should be transmitted;

 (d) transmitting the first radio frequency
signal carrying the first craft's position;

20 (e) receiving the first radio frequency signal
at a monitoring receiver of a second craft;

 (f) decoding at the monitoring receiver of the
second craft the first craft's position from the first
radio frequency signal;

25 (g) displaying the position of the first craft
at the monitoring receiver of the second craft; and

 (h) repeating steps (a) through (g).

30 23. A method of tracking the position of a first
craft by a monitoring receiver, the first craft and the
monitoring receiver being within a predetermined range of
each other, as defined in claim 22 wherein the step of
determining the first craft's position comprises the step
of determining the first craft's position using a LORAN
receiver.

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24. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of determining the first craft's position comprises the step of determining the first craft's position using a GPS receiver.

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25. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the first craft's position is defined in reference to the latitude and longitude of the first craft.

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26. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 25 wherein the step of determining the first craft's position further comprises the step of determining the altitude of the first craft.

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27. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claims 25 or 26 wherein the step of encoding the first craft's position comprises the step of encoding the position of the craft into a digital pulse train.

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28. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 27 wherein the step of encoding the position of the first craft's position further comprises the step of translating the position of the craft into an audio signal.

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29. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 further comprising the step of avoiding conflicts with any conflicting radio frequency signals in the airspace.

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30. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of listening for any conflicting radio frequency signals.

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31. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a period of time prior to transmission.

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32. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a predetermined period of time prior to transmission.

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33. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 or 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of transmitting a radio frequency signal in a non-interrogation manner.

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34. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in the frequency range from about and including the VHF band to about and including the SHF band.

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35. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in a substantially omnidirectional pattern.

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36. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of encoding the position of the first craft further comprises the step of encoding an identification code for the first craft so that the identification code can be carried by the first radio frequency signal and wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the identification code for the first craft.

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37. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 further comprising the step of avoiding conflicts with any conflicting radio frequency signals in the airspace.

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38. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of displaying the position of the first craft at the monitoring position comprises the step of repeatedly displaying the position of the first aircraft on a display as the aircraft changes position.

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39. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of displaying the position of the first craft at the

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1 monitoring position further comprises the step of
displaying the heading and the speed of the first craft on
a display.

5 40. A method of tracking the position of a first
craft by a monitoring receiver, the first craft and the
monitoring receiver being within a predetermined range of
each other, as defined in claim 38 comprises the step of
10 displaying the position of the second craft on a display,
the second craft having the monitoring receiver on board

15 41. A method of tracking the position of a first
craft by a monitoring receiver, the first craft and the
monitoring receiver being within a predetermined range of
each other, as defined in claim 40 further comprising the
step of determining the location of the second position
relative to the fixed reference and wherein the step of
20 displaying the position of the first craft comprises the
step of displaying the position of the first craft and the
location of the monitoring receiver on the display.

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42. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, the method comprising the steps of:

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(a) determining on board the first craft using an existing automated navigational system the first craft's position in at least two perpendicular planes of space which are of interest to the second craft;

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(b) encoding the first craft's position in a form which can be carried by a first radio frequency signal;

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(c) determining whether the first radio frequency signal will conflict with any other radio frequency signals;

(d) transmitting the first radio frequency signal carrying the first craft's position;

(e) receiving the first radio frequency signal at the second craft;

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(f) decoding the first craft's position from the first radio frequency signal;

(g) apprising the operator of the second craft when the position of the first craft is within an advisory range; and

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(h) repeating steps (a) through (g).

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43. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 42 wherein the step of determining the first craft's position comprises the step of receiving a LORAN signal and determining a position in latitude and longitude.

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1 44. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
5 defined in claim 42 wherein the step of determining the
first craft's position comprises the step of receiving a
GPS signal.

10 45. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 42 wherein existing automated navigational
system is available both within and without the
predetermined range.

15 46. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 45 wherein the step of determining the
20 first craft's position comprises the step of determining
its position in latitude and longitude.

25 47. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 45 wherein the step of determining the
first craft's position further comprises the step of
determining the altitude of the first craft.

30 48. A method for announcing the position of a first
aircraft at a first position to a receiver located at a
second position as defined in claim 46 or 47 wherein the
step of avoiding conflicts with any conflicting radio
frequency signals in the airspace comprises the step of

1 transmitting a radio frequency signal in a noninterrogation
manner.

5 49. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 46, 47 or 48 wherein the step of encoding
10 the first craft's position comprises the step of encoding
the position of the first craft into a digital pulse train.

15 50. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 49 wherein the step of encoding the
position of the first aircraft further comprises the step
of translating the first craft's position into an audio
signal.

20 51. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 49 wherein the step of determining whether
25 the first radio frequency signal will conflict with any
other radio frequency signals comprises the steps of:

listening for any conflicting radio frequency
signals; and

waiting a period of time prior to transmission.

30 52. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 51 wherein the step of waiting a period of

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1 time comprises the step of waiting a randomly assigned
period of time.

5 53. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 42 wherein the step of encoding the first
10 craft's position comprises the step of encoding an
identification code for the first craft so that the
identification code can be carried by the first radio
frequency signal and wherein the step of transmitting the
first radio frequency signal comprises the steps of:

15 transmitting the first radio frequency signal in
the frequency range from about and including the VHF
band to about and including the SHF band and
frequency signal;

transmitting the first radio frequency signal in
a substantially omnidirectional pattern; and

20 transmitting the identification code for the
first craft.

25 54. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as
defined in claim 42 wherein the step of apprising the
operator comprises the step of repeatedly displaying the
position of the first craft on a display as the first craft
changes position.

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55. A method of tracking the position of a first
craft from on board a second craft, the first and second
craft being within a predetermined range of each other, as

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1 defined in claim 54 wherein the step of apprising the
operator of the second craft comprises the steps of:
displaying the relative position and direction of
5 travel of the first craft on a display; and
displaying the position of the second craft on a
display.

10 56. A method of avoiding collisions between a first
craft having a first identification code and at least a
second craft having a second identification code, the first
and second crafts coming within a predetermined range of
each other, the method comprising the steps of:

15 (a) determining, on board to the first craft and
using an existing automated navigational system, the
first craft's position in at least one plane in space
which is of interest to the second craft to avoid a
collision with the first craft;

20 (b) encoding the first craft's position and
identification code to be carried by a first radio
frequency signal;

(c) listening for any radio frequency signals
present on the same frequency allocation as the first
radio frequency signal;

25 (d) transmitting the first radio frequency
signal carrying the first craft's position and
identification code;

(e) receiving the first radio frequency signal
at the second craft;

30 (f) decoding the first craft's position and
identification code from the first radio frequency
signal;

35 (g) determining the second craft's position, on
board the second craft by using an existing automated
navigational system, and in at least one dimension of

1 space, which is of interest to the operator of the
second craft, to avoid a collision with the first
craft;

5 (h) displaying, on board the second craft, the
position of the first craft and the location of the
second craft so that the operator of the second craft
is apprised of the location of the both the first
craft and the second craft so as to avoid a collision
therebetween; and

10 (i) repeating steps (a) through (h).

57. A method of avoiding collisions between a first
craft having a first identification code and at least a
15 second craft having a second identification code, the first
and second craft coming within a predetermined range of
each other, as defined in claim 56 wherein the step of
determining the first craft's position comprises the step
of receiving a LORAN signal or a GPS signal.

20 58. A method of avoiding collisions between a first
craft having a first identification code and at least a
second craft having a second identification code, the first
and second craft coming within a predetermined range of
each other, as defined in claim 57 wherein the first craft
25 comprises an aircraft and wherein the step of determining
first craft's position comprises the step of determining
the latitude, longitude, and altitude of the first
aircraft.

30 59. A method of avoiding collisions between a first
craft having a first identification code and at least a
second craft having a second identification code, the first
and second craft coming within a predetermined range of
each other, as defined in claim 56 wherein the step of
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1 encoding the first craft's position comprises the step of
encoding the latitude and longitude of the first craft into
a digital pulse train which can be carried by a frequency
5 modulated first radio frequency signal.

60. A method of avoiding collisions between a first
craft having a first identification code and at least a
second craft having a second identification code, the first
10 and second craft coming within a predetermined range of
each other, as defined in claim 56 further comprises the
step of step of waiting a period of time after a
conflicting radio frequency signal is heard prior to
transmission of the first radio frequency signal, the
15 period of time being different for the first craft and the
second craft, the transmission of the first radio frequency
signal being initiated without interrogation from another
radio frequency signal.

20 61. A method of avoiding collisions between a first
craft having a first identification code and at least a
second craft having a second identification code, the first
and second craft coming within a predetermined range of
each other, as defined in claim 56 wherein the step of
25 transmitting the first radio frequency signal comprises the
step of transmitting the first radio frequency signal in
the frequency range from about and including the VHF band
to about and including the SHF band in a substantially
omnidirectional pattern.

30 62. A method of avoiding collisions between a first
craft having a first identification code and at least a
second craft having a second identification code, the first
and second craft coming within a predetermined range of
each other, as defined in claim 56 wherein the step of
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displaying the position of the first craft comprises the step of displaying the relative direction of travel of the first craft on a display.

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63. An apparatus for announcing the position of a first aircraft at a first position within airspace capable of containing a plurality of other aircraft, to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, the apparatus comprising:

means for making an on board determination of the position of the first aircraft using the existing navigational system;

means for encoding the position of the first aircraft into information which can be carried by a first radio frequency signal;

means for detecting the presence of any conflicting radio frequency signal which would interfere with the first radio frequency signal and determining whether transmission of the first radio frequency should proceed;

means for transmitting the first radio frequency signal, from the first aircraft, carrying the position information of the first aircraft such that the radio frequency signal can be received at the receiver, decoded, and the position of the first aircraft announced at the receiver.

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64. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range

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of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for making an on board determination of the position of the first aircraft comprises a LORAN receiver.

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65. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for making an on board determination of the position of the first aircraft comprises a GPS receiver.

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66. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for making an on board determination of the position of the first aircraft comprises means for determining the latitude and longitude of the first aircraft.

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67. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 66 wherein the means for making an on

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board determination of the position of the first aircraft further comprises means for determining the altitude of the aircraft.

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68. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for transmitting the first radio frequency signal comprises a radio frequency transmitter operating in a frequency range from about and including the VHF band to about and including the SHF band.

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69. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 68 wherein the means for transmitting the first radio frequency signal further comprises an omnidirectional antenna.

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70. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for detecting the presence of any conflicting radio frequency signal comprises a radio frequency receiver.

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71. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for encoding the position of the first aircraft is further for encoding an identification code into information which can be carried by the first radio frequency signal.

72. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 further comprising:

means for receiving a second radio frequency signal carrying the position and identification code for a second aircraft;

means for decoding the second aircraft's position and identification code from the second radio frequency signal; and

means for displaying, on board the first aircraft, the second aircraft's position and identification code decoded from the second radio frequency signal so that the operator of the first craft is apprised of the position of the second aircraft.

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73. An apparatus for tracking the position of a second craft from on board a first craft, the first and the second craft being within range of an existing navigational system and within a predetermined range of each other, the apparatus comprising:

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means, on board the first craft, for receiving a determination of the position of the first craft using the existing navigational system, the position of the first craft being determined in at least two planes of interest to the operator of the second craft;

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means for encoding the first craft's position in a form which can be carried by a first radio frequency signal;

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means for transmitting the first radio frequency signal carrying the first craft's position;

means for receiving a second radio frequency signal carrying the second craft's position;

means for decoding the second craft's position from the second radio frequency signal;

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means for displaying, on board the first craft, the second craft's position decoded from the second radio frequency signal so that the operator of the first craft is apprised of the position of the second craft.

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74. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 73 wherein the means for receiving an on board determination of the position of the first craft comprises a data port adapted to receive data from a LORAN receiver.

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75. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 73 wherein the means for receiving an on board determination of the position of the first craft comprises a data port adapted to receive data from a GPS receiver.

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76. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 73 wherein the means for transmitting the first radio frequency signal comprises:

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a radio frequency transmitter operating in a frequency range from about and including the VHF band to about and including the SHF band; and
an omnidirectional antenna system.

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77. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 76 wherein the means for detecting the presence of any conflicting radio frequency signal comprises a radio frequency receiver.

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78. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 77 wherein the means for encoding the first craft's position is further for encoding an identification code into information which can be carried by the first radio frequency signal.

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79. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first craft being within range of an existing navigational system and the first and the second craft being within a

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predetermined range of each other, the apparatus comprising:

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means for determining, on board the first craft and using the existing navigational system, the first craft's position in at least one plane in space which is of interest to the second craft to avoid a collision with the first craft;

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means for encoding the first craft's position and the first identification code to be carried by a first radio frequency signal;

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means for detecting the presence of any conflicting radio frequency signal and determining whether transmission of the first radio frequency should proceed;

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means for transmitting the first radio signal carrying the first craft's position and identification code;

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means for receiving, on board the first craft, a second radio frequency signal transmitted from the second craft, the second radio frequency signal carrying the position of the second craft and the second identification code;

25

means for decoding, on board the first craft, the second craft's position and identification code;

30

means for simultaneously displaying the first craft's position and the second craft's position on board the first craft so that the operator of the first craft is apprised of the position of the second craft so as to avoid a collision therebetween.

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80. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 79 where in the means for determining the first craft's position comprises a LORAN receiver.

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81. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 79 where in the means for determining the first craft's position comprises a GPS receiver.

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82. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 80 or 81 wherein the means for transmitting the first radio frequency signal comprises:

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a radio frequency transmitter operating in a frequency range from about and including the VHF band to about and including the SHF band; and
an omnidirectional antenna system.

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83. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 82 wherein the means for detecting the presence of any conflicting radio frequency signal comprises a radio frequency receiver.

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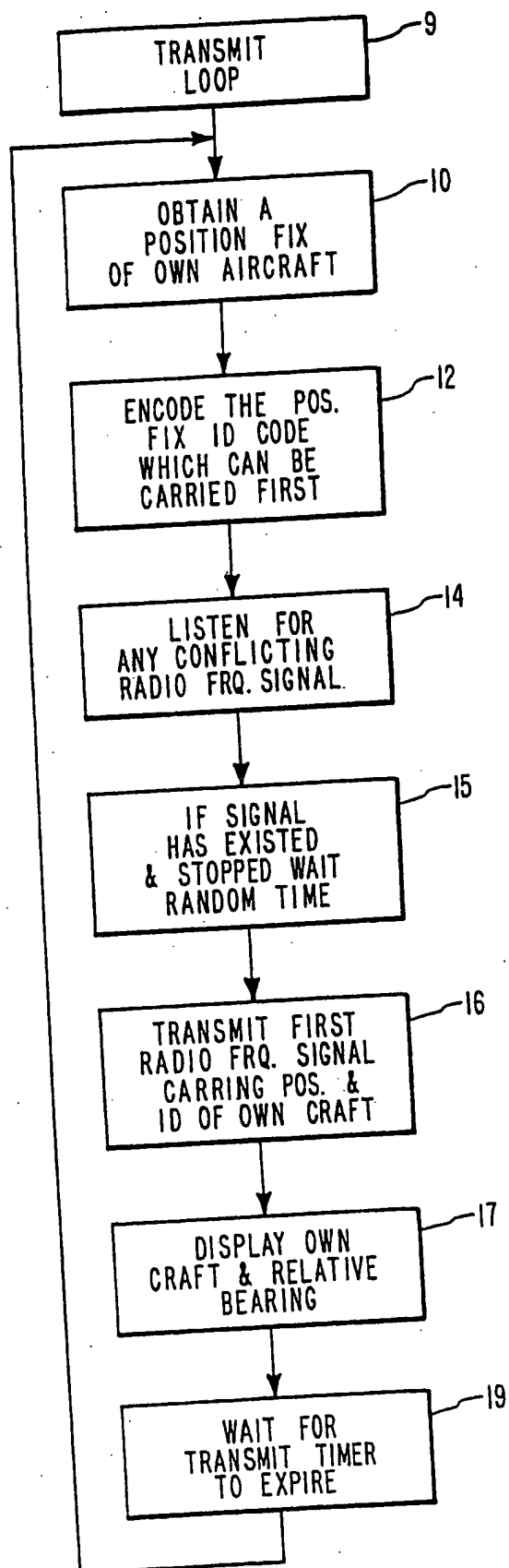


FIG. 1A

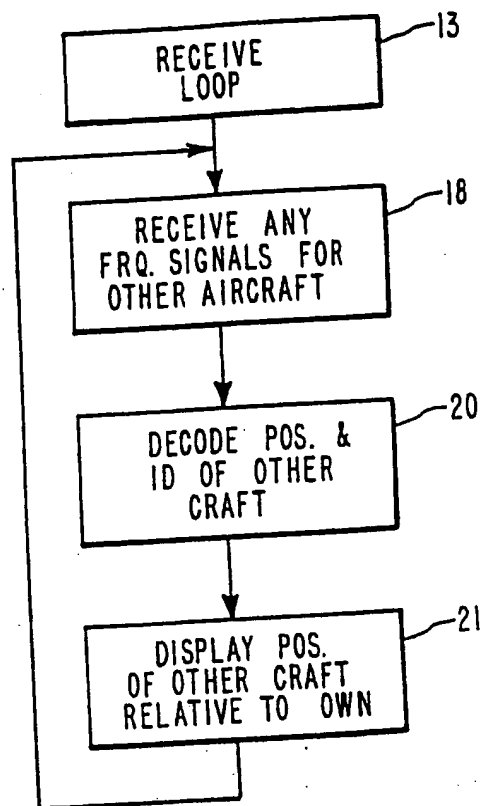
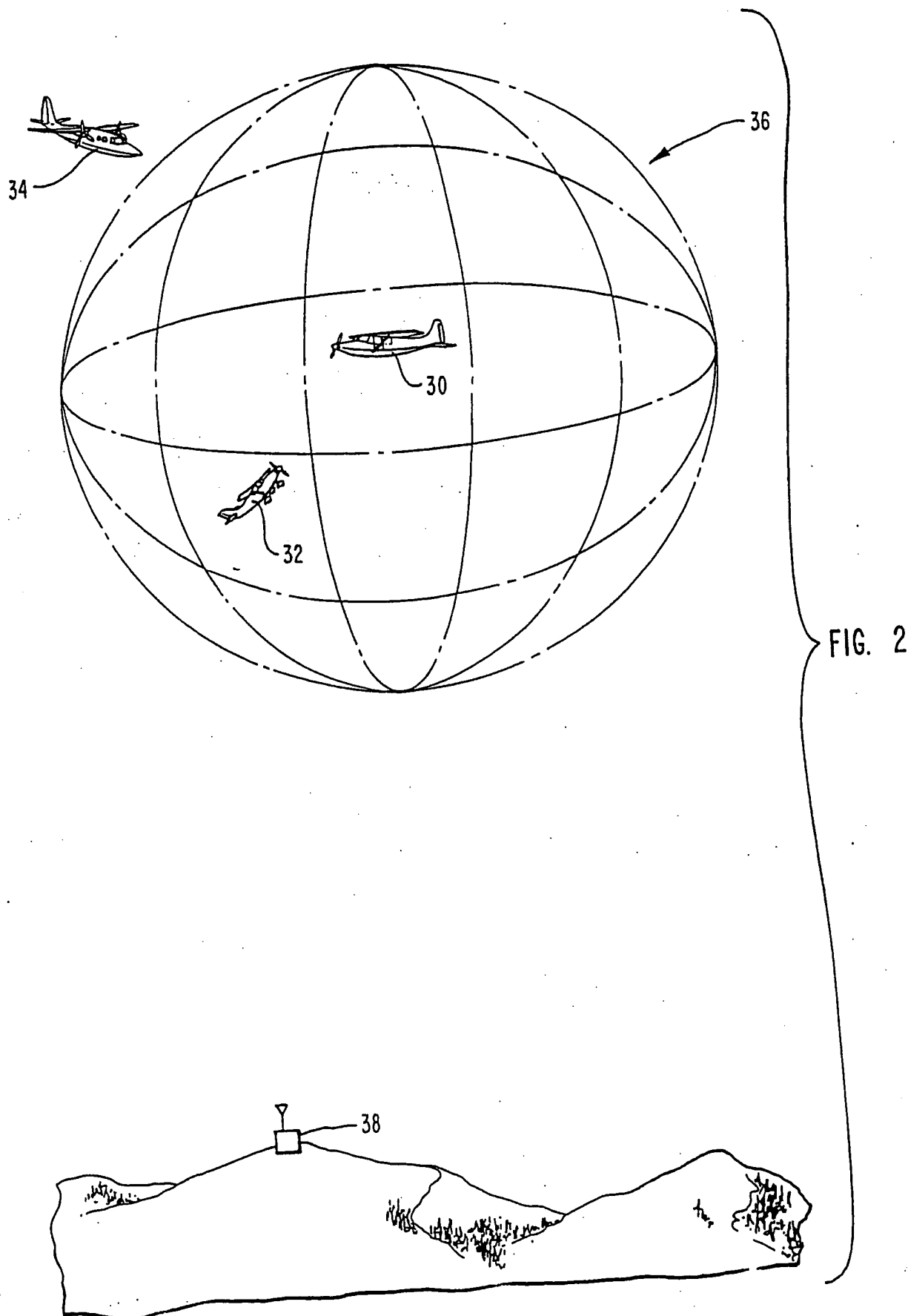


FIG. 1B

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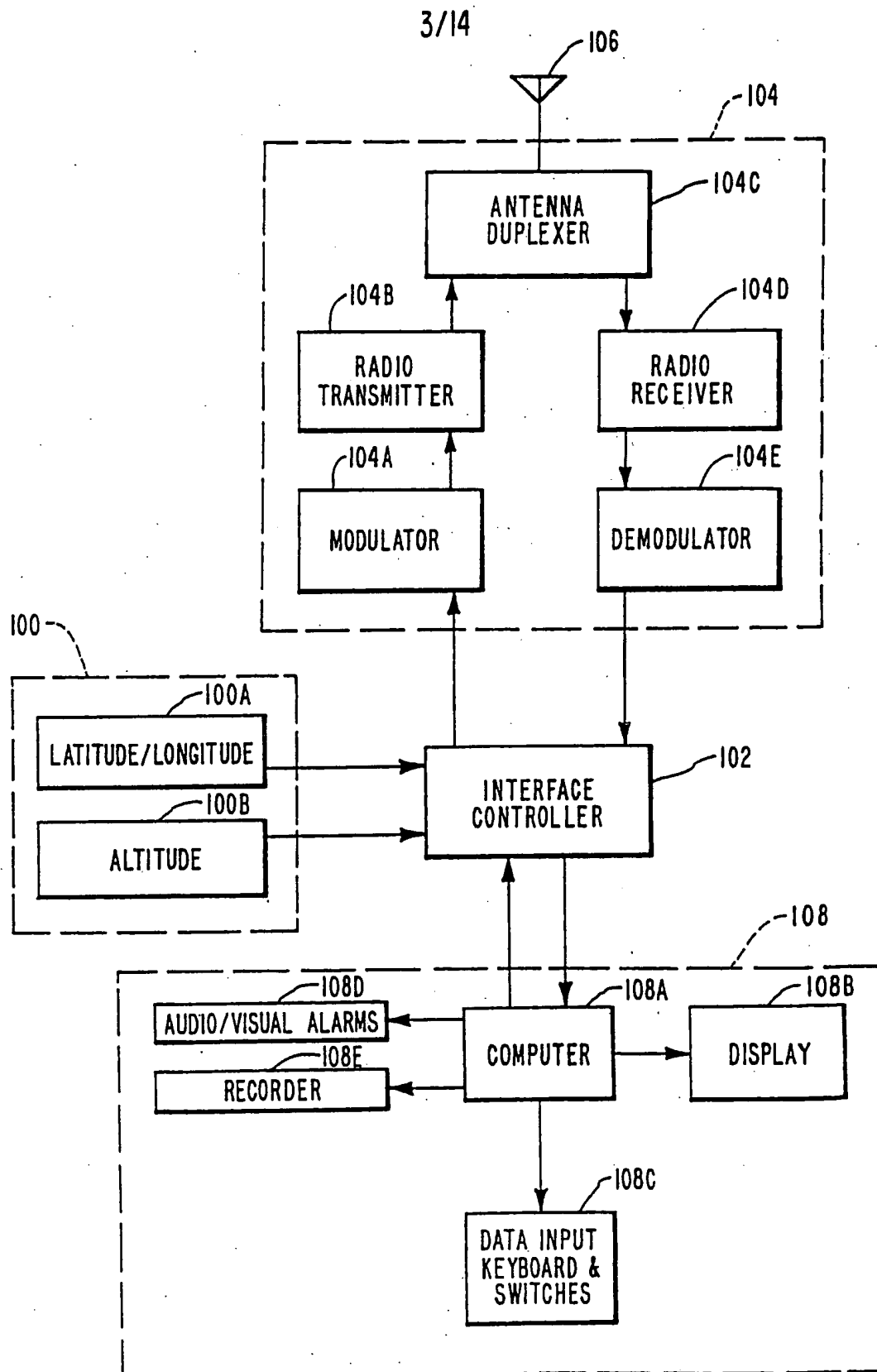


FIG. 3

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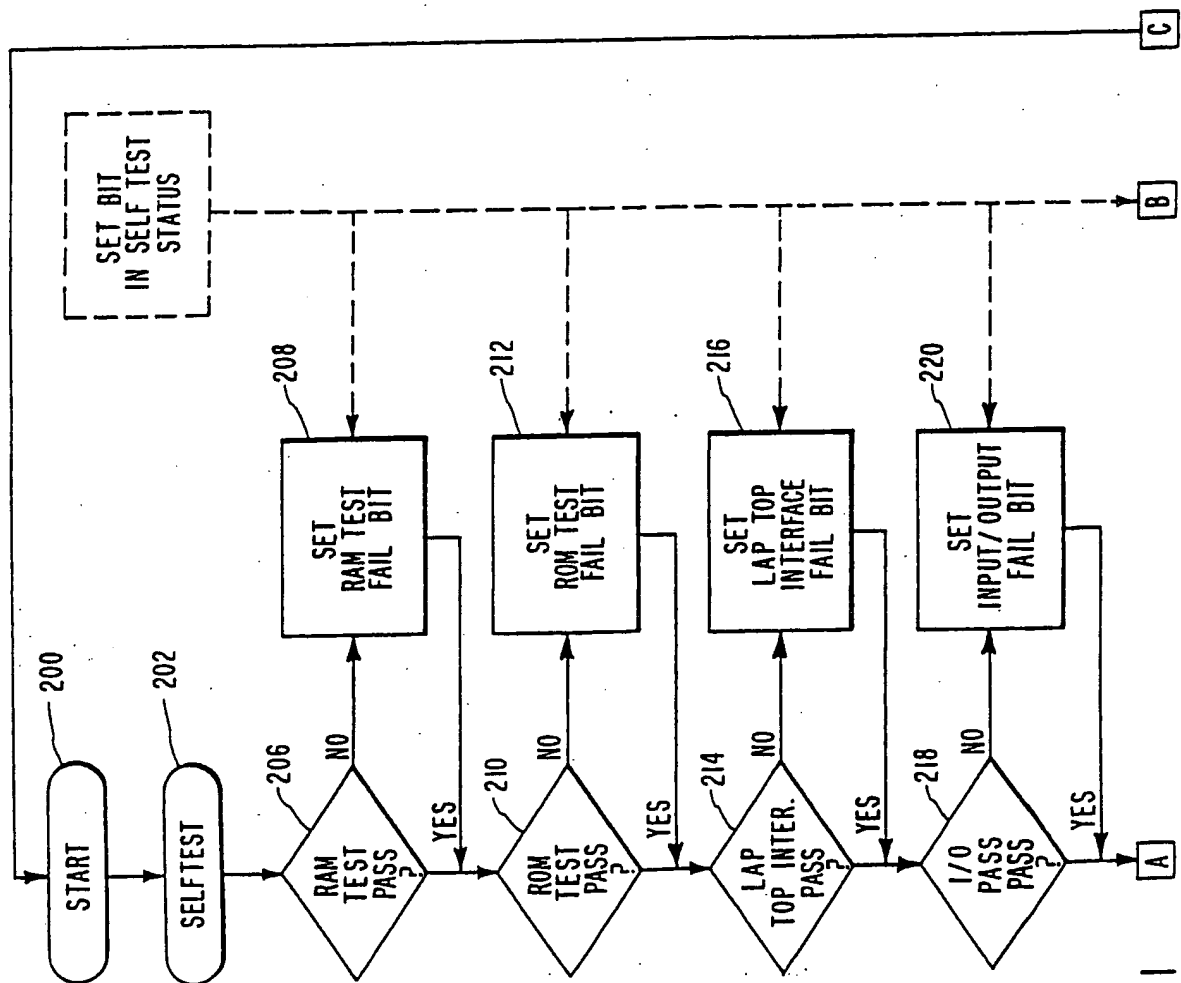


FIG. 4-1

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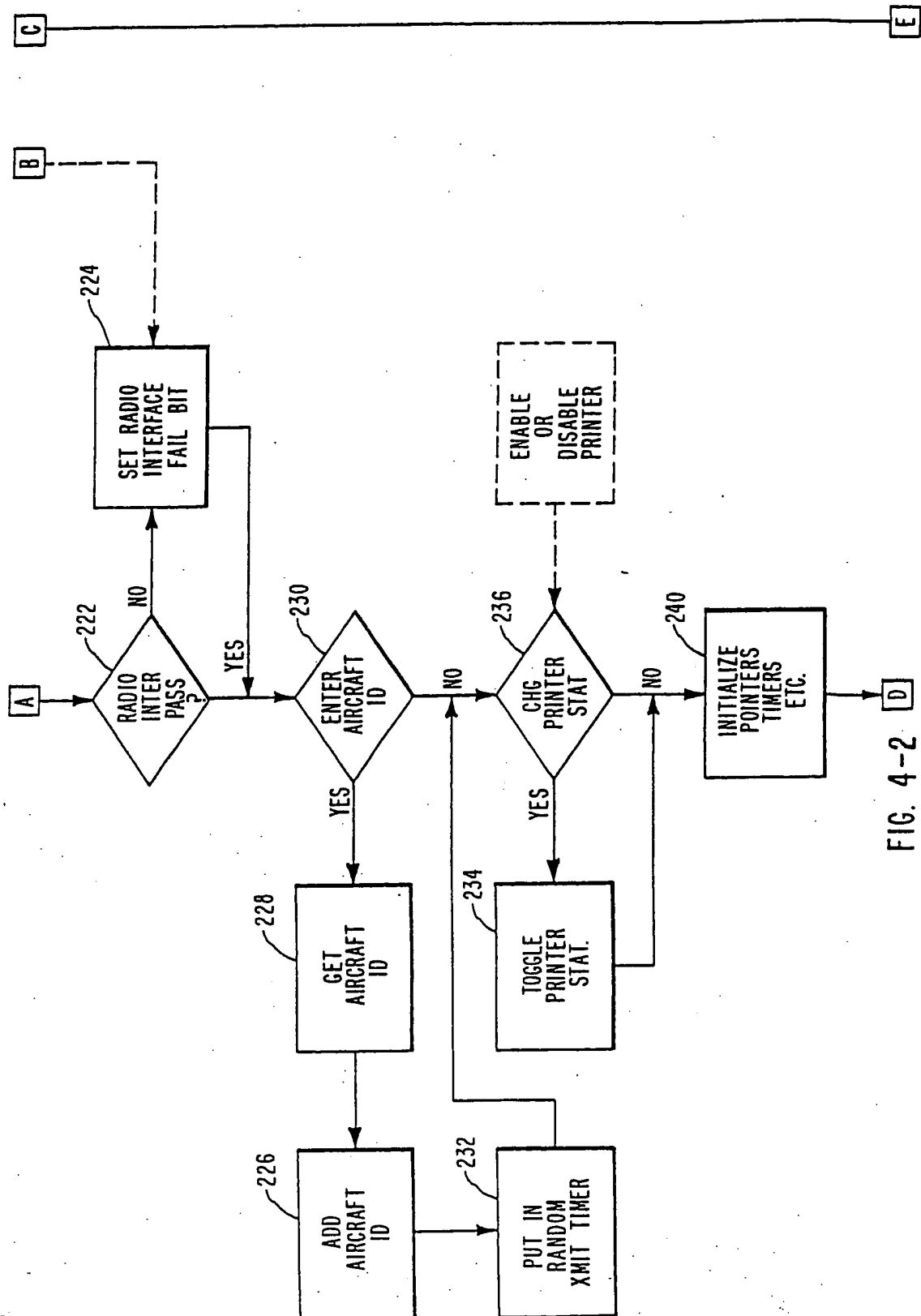


FIG. 4-2

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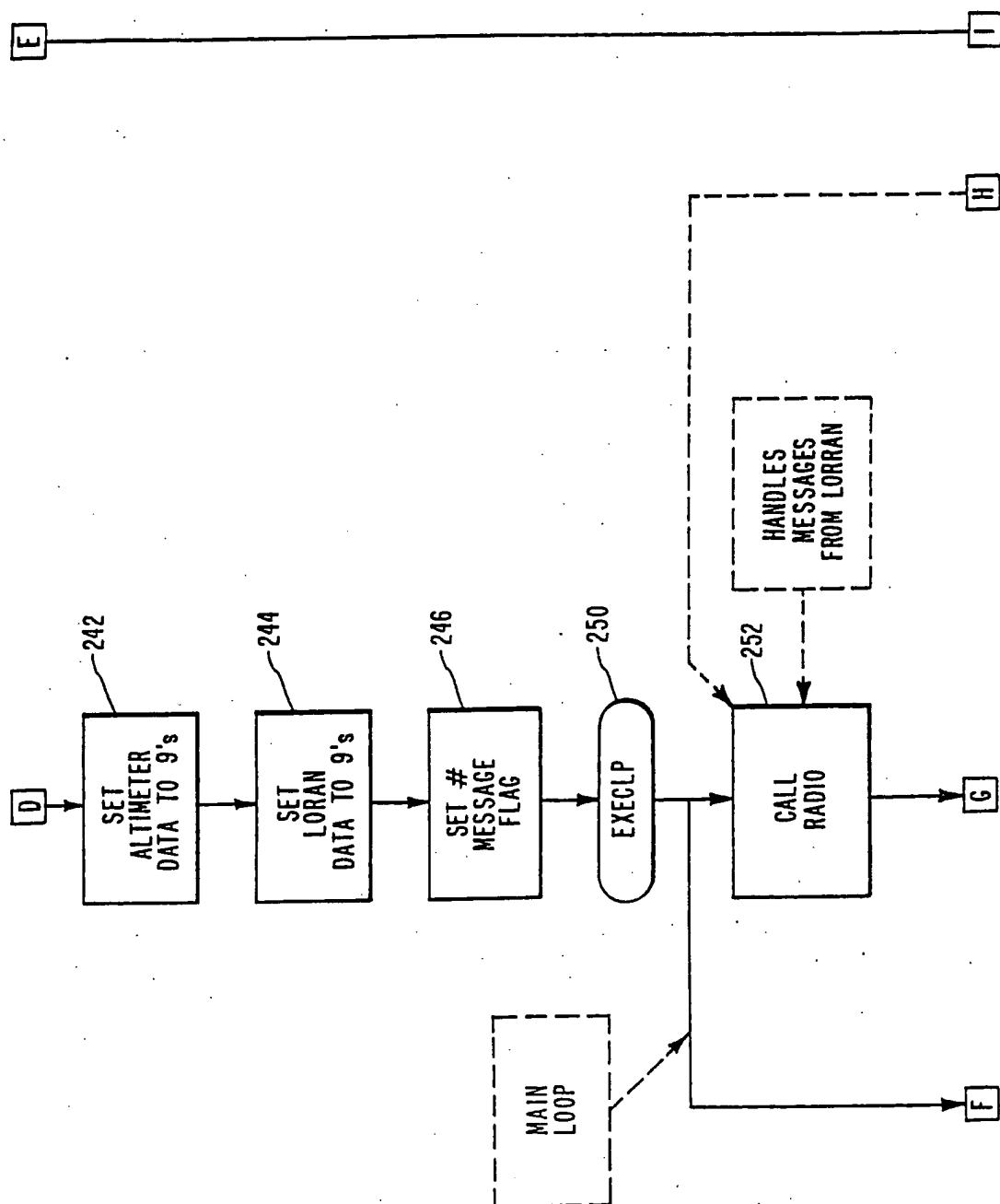


FIG. 4-3

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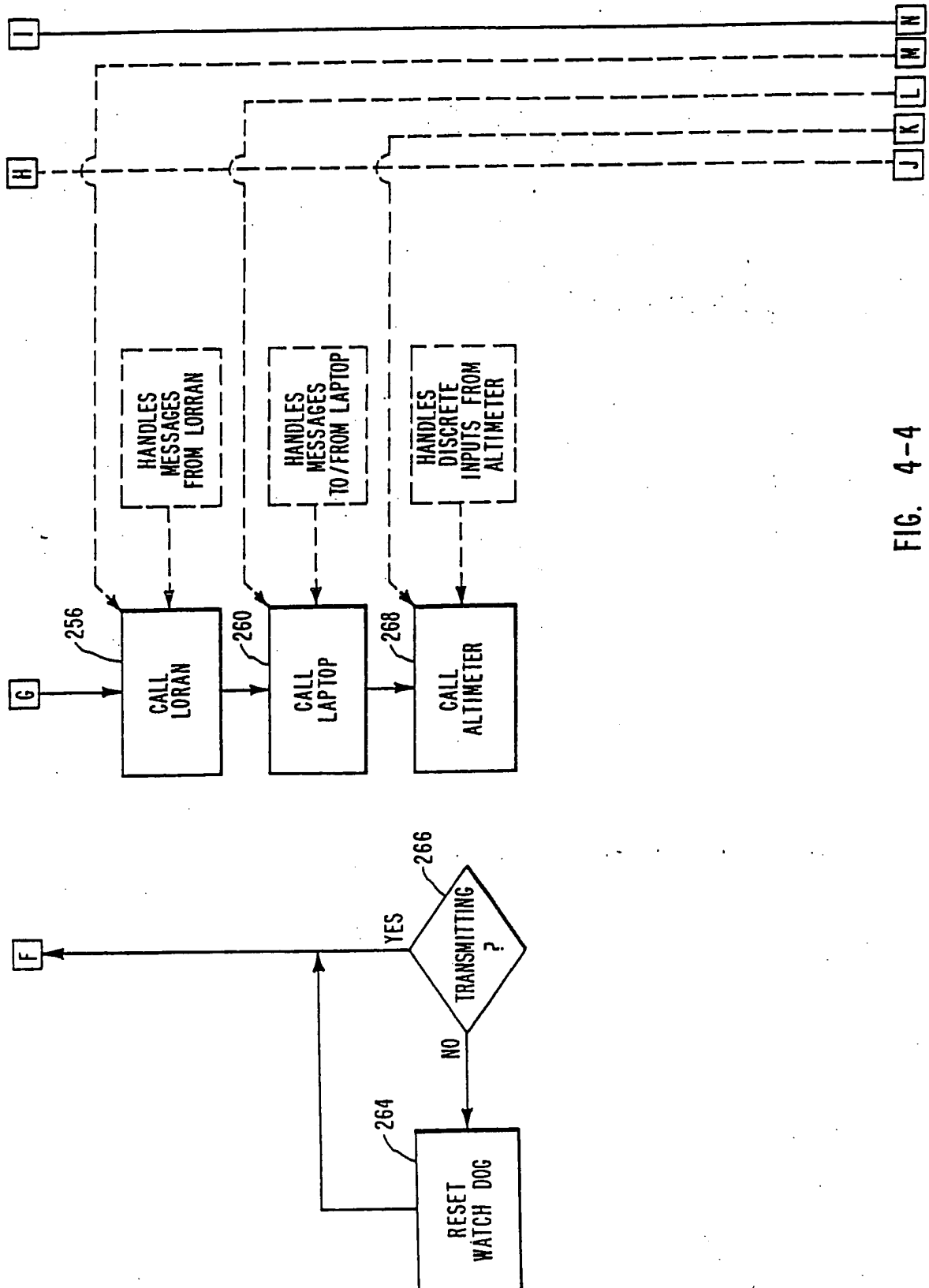


FIG. 4-4

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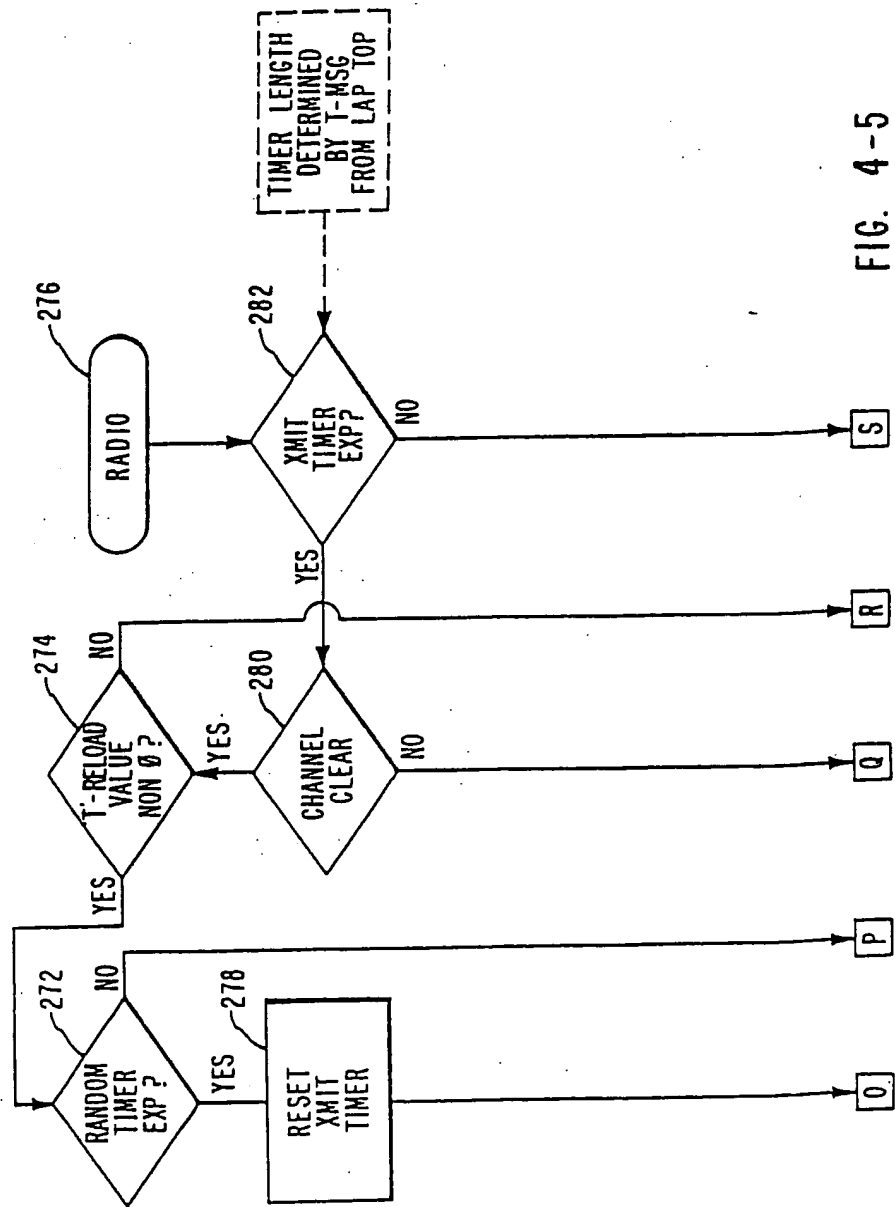
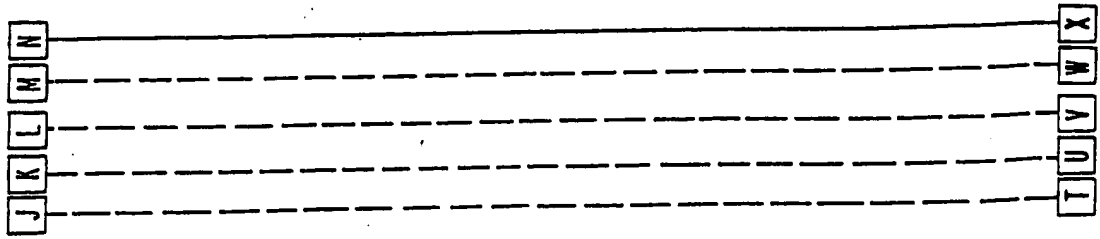


FIG. 4-5

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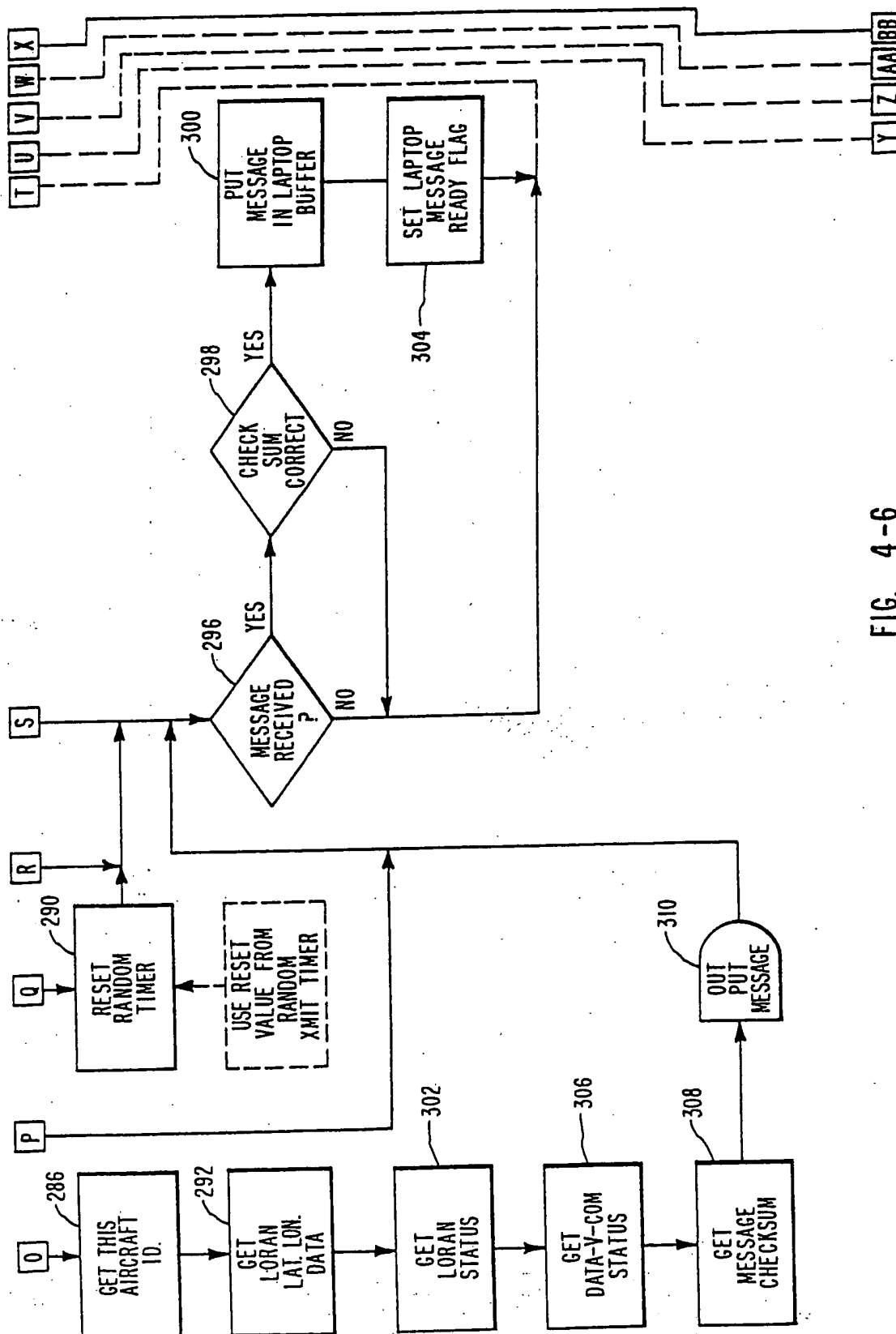
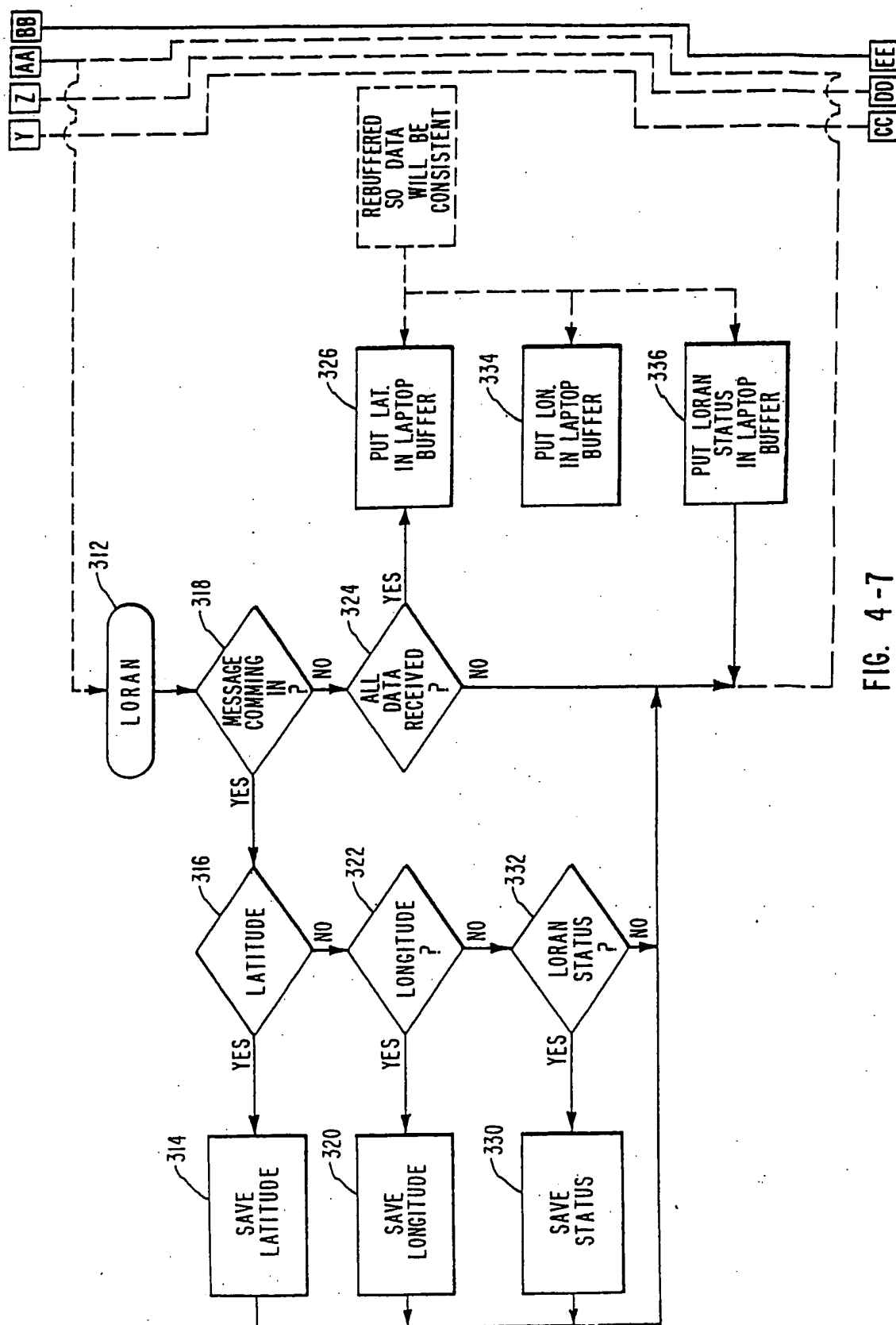


FIG. 4-6

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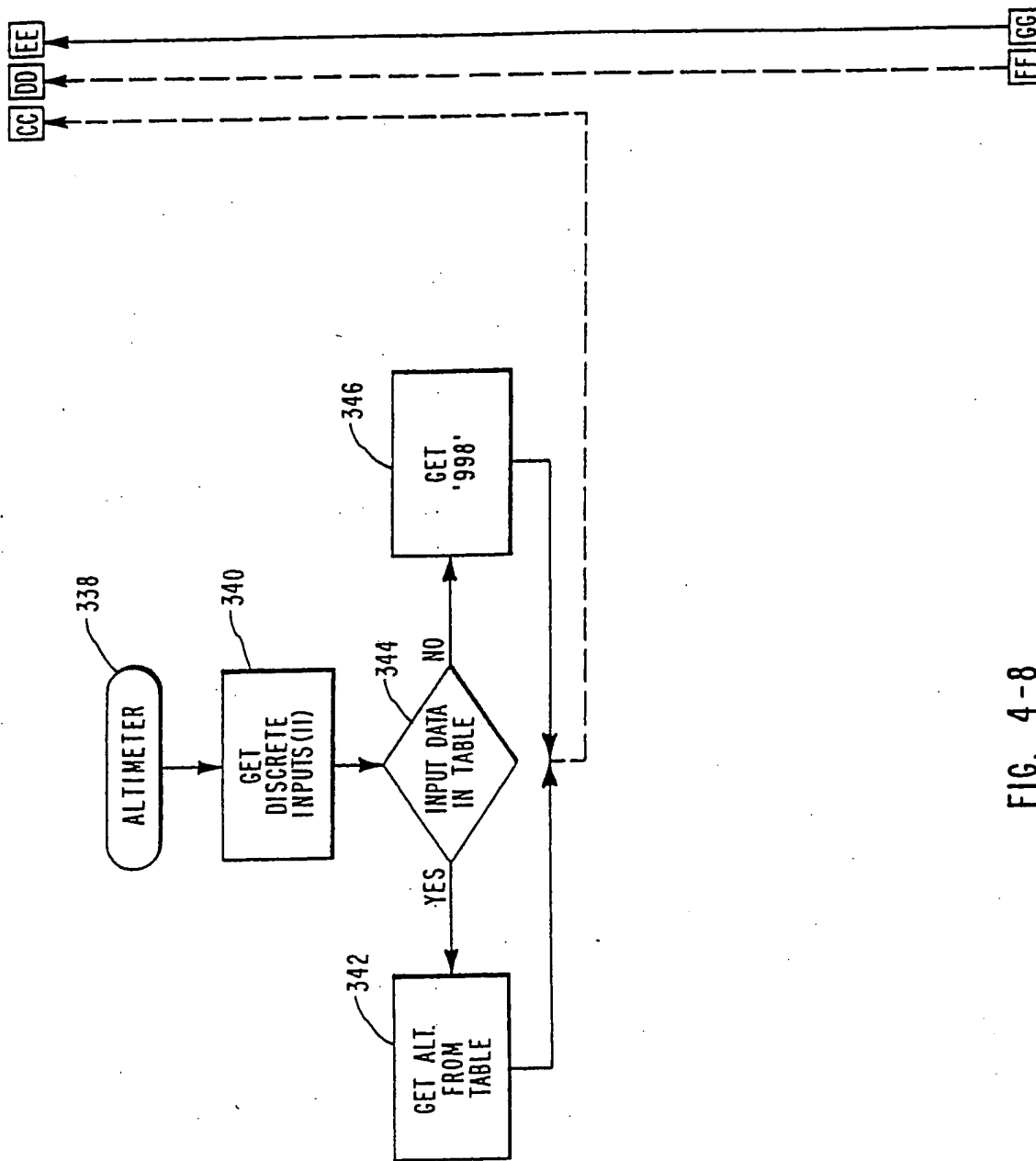


FIG. 4-8

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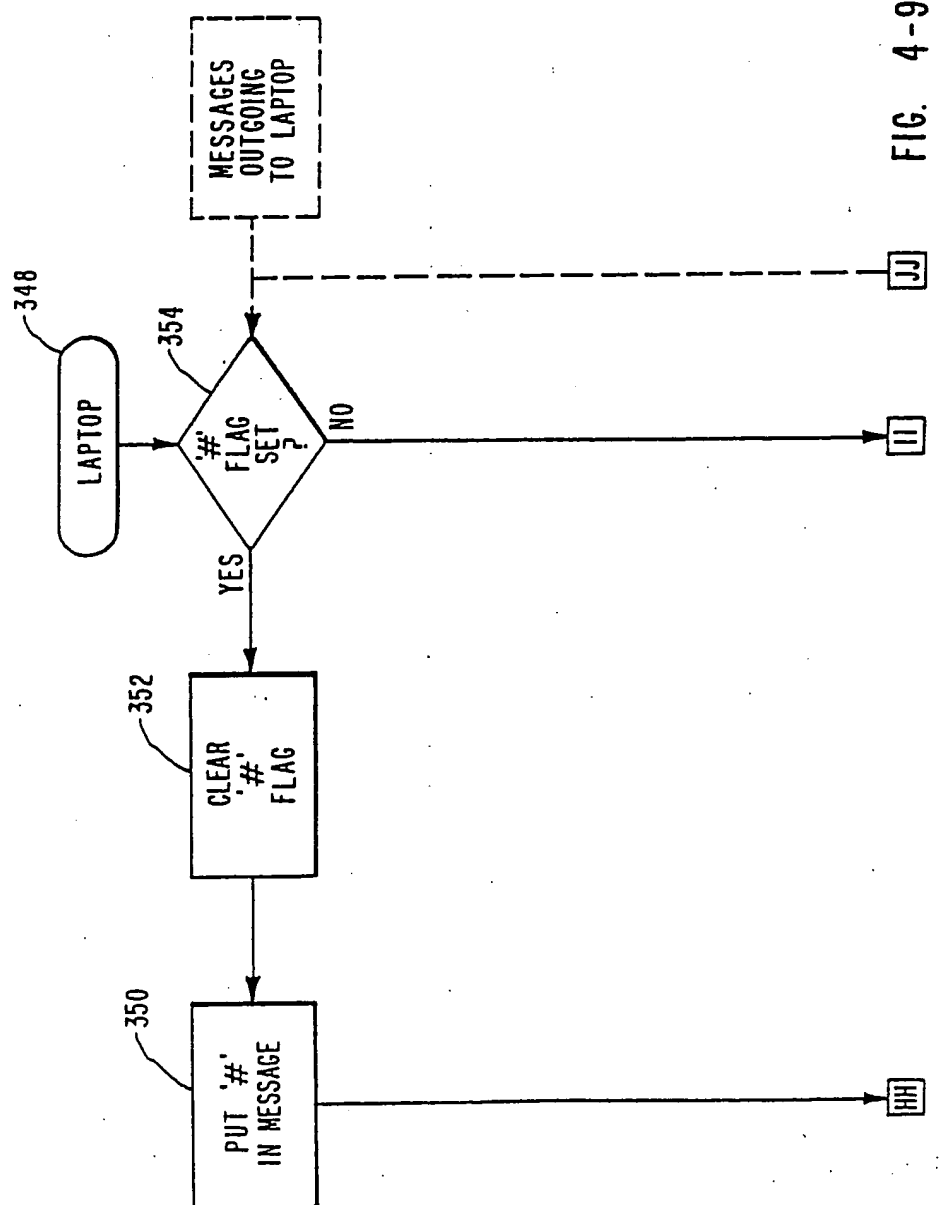
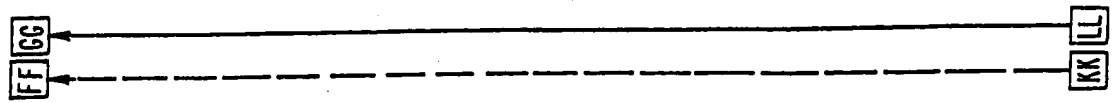


FIG. 4-9

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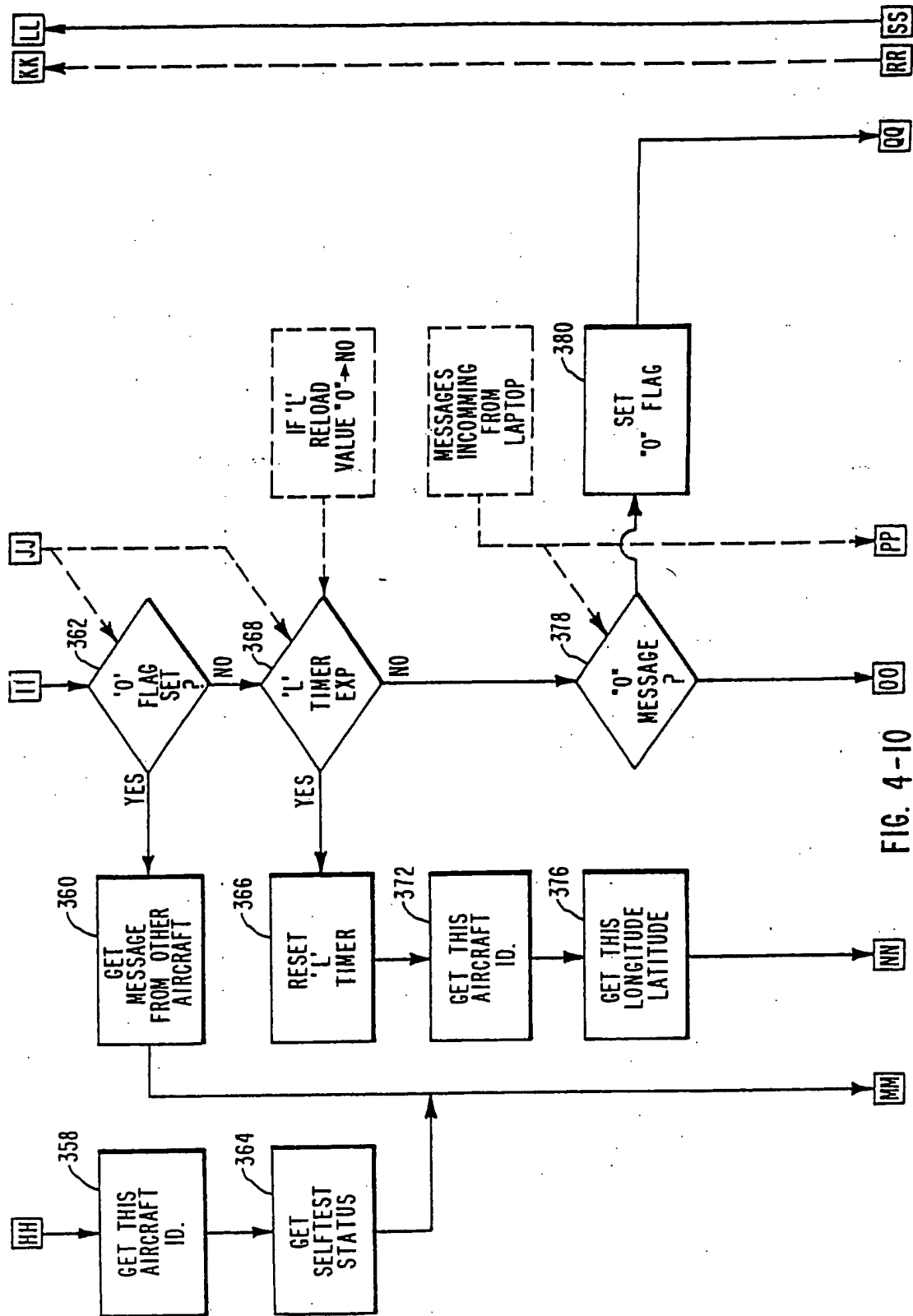


FIG. 4-10

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/05738

CLASSIFICATION OF SUBJECT MATTER
 IPC(5): G01S 3/02
 US CL : 364/452,461; 340/961; 342/29,41,455

FIELDS SEARCHED
 U.S. 364/452,459,460,461
 340/961
 342/29,30,31,32,41,450,451,455,463

Documentation Searched other than Minimum Documentation
 to the extent that such Documents are included in the Fields Searched

III DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No. 1
X	US, A, 4,835,537 (MANION) 30 MAY 1989 See figs. 1,3,5,7,8 and cols. 2-5,7,11-14.	1-83
A	US, A, 5,043,903 (CONSTANT) 27 AUGUST 1991	
A	US, A, 3,750,166 (DEARTH) 31 JULY 1973	
A	US, A, 4,384,208 (MARINELLI ET AL.) 28 NOVEMBER 1989	

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 - "O" document referring to an oral disclosure, use, exhibition or other means
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 - "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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 - "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
 - "Z" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search: 19 NOVEMBER 1991

Date of Mailing of this International Search Report: 25 NOV 1991

International Searching Authority: ISA/US

Signature of Authorized Officer: *Andrie R. Korman*
 GARY CHIN